NATIONAL PUBLIC RADIO

Report to the Corporation for Public Broadcasting

Digital Radio Coverage & Interference Analysis (DRCIA) Project: Station Field Measurement Report Deliverable 6.2

CPB Account No. 10446
Reporting Date: July 27, 2007

INTRODUCTION

NPR is pleased to present the Corporation for Public Broadcasting this interim report on Station Field Measurements for the Digital Radio Coverage and Interference Analysis project. This update reviews NPR's design and development of the measurement system, the measurement of stations, and preliminary results of the field measurements. All 10 stations required by the contract have been field-measured, with assistance from the firms of Cavell, Mertz, Inc. and Hammett and Edison, Inc.

NPR'S FIELD MEASUREMENT OF IBOC DAB STATIONS (DELIVERABLE 6.2)

Selections of Stations

As detailed in our DRCIA report of June 29, we developed a preliminary model for prediction of IBOC coverage, based on RF performance measurements of consumer IBOC receivers in NPR Labs. We supplied the initial model parameters to Hammett & Edison, which also performed our earlier analysis of stations for CPB in November. Using a CPB-supplied list of 282 public radio stations expected to be currently transmitting in IBOC, the computer study estimated the loss of IBOC service caused by signal interference for each station. This list helped us identify candidates for the 10 stations that we measured for this report.

Our selection of ten stations for field measurement combined several objectives. First, we wanted to measure a few stations identified by the computer prediction with the highest interference. We also wanted some stations with an average (mid-list) amount of interference, and finally one with low interference to "anchor" the model. Other factors entering the selection criteria included the population predicted to receive interference, geography, and of course, whether the station was transmitting normally in hybrid IBOC mode. The stations selected for measurement, ranked by the estimated percentage of interference area, are listed below:

WWFM, Ch. 206A, Trenton, New Jersey (30%)
KMPO, Ch. 204B, Modesto, California (28%)
WMUB, Ch. 203B, Oxford, Ohio (26%)
KQEI-FM, Ch. 207A, North Highlands, California (23%)
KVPR, Ch. 207B, Fresno, California (14%)
WNCU, Ch. 214C2, Durham, North Carolina (14%)
KXPR, Ch. 205B, Sacramento, California (8%)
WFYI-FM, 211B, Indianapolis, Indiana (4%)
WHRV, Ch. 208B, Norfolk, Virginia (3%)
WBEZ, Ch. 218B, Chicago, Illinois (0%)

MEASUREMENT INSTRUMENTATION

We developed an unprecedented system to collect the signal data, based on NPR Labs' previous success with the Kenwood KTC-HR100 IBOC DAB tuner for cars. This tuner is still among the best-performing IBOC receivers in RF sensitivity and strong-signal rejection, and is recognized for its ability to provide IBOC receive status and calibrated signal power measurements with NPR's portable field test units.

Because our IBOC prediction model indicated the strong importance of adjacent-channel signal interference, we decided to connect four KTC-HR100 tuners into our portable logger. One tuner operated "AUTO" mode to allow normal reception of IBOC or analog FM, as receive conditions required. This is the operation used previously by NPR Labs for its signal measurements. However, we realized that in the AUTO mode the tuner operates with an IF bandwidth of at least 500 kHz (±250 kHz), which is susceptible to signal leakage from adjacent channel stations, which in this study we intentionally wanted to approach, geographically, to determine interference impact.

We determined that when the Kenwood tuner was set to the "ANALOG" mode it utilizes a separate IF filter that is substantially narrower than the IBOC filter. In fact, we modified the units with new ceramic filters having a bandwidth of approximately 150 kHz that suppress the adjacent channel carrier by 30 dB.

We put a Kenwood tuner, set to ANALOG and tuned to the desired station, into a separate field test unit cabinet along with two identically-modified tuners, tuned to the upper and lower adjacent channels. The signal voltages from these tuners were connected to the logger board in the primary field test unit, as shown in Figure 3. The primary logger collected the signals from all four tuners, along with GPS coordinate data and UTC time stamps, for storage on the logger's memory card.

We also developed a unique active filter in the logger units to remove Raleigh fading component of the mobile signal at speeds above 20 miles per hour, without affecting the log-normal signal power distribution. This filter significantly increased the accuracy of the local mean field strength measurement that we wished to gather.

The results of the entire drive-test measurement of each station are shown in Appendix B, following the reference contour maps and the drive-test dot overlay maps. The signal power (in dBm) of the desired station is shown in dark blue. The signal powers for the upper and lower adjacent channels are shown in purple and yellow, respectively.

The memory card files were post-processed to remove data while driving (below 20 MPH). This improves the model accuracy by eliminating parts of the drive-test route where the vehicle was stopped or traveling at speeds too slow for the local mean field strength to be reliably measured.

Another important part of the measurement system was the development of a calibrated groundplane antenna, which improved the accuracy of field strength measurements by helping to isolate the antenna from the effects of irregular vehicle roofs and bodies. This antenna was built to NPR Lab's specifications by Kintronic Labs and calibrated at the Institute for Telecommunication Sciences in Boulder, Colorado. A picture of the antenna on a test vehicle is shown in Figure 1 and a diagram of the antenna is included in Figure 2.

MAP PRESENTATION

The maps of all ten stations are shown in three-page groups in Appendix B, listed in alphabetical order by call sign. The first page for each station shows the standard F(50,50) 60 dBu contour of the desired station in green. The F(50,10) 54 dBu contours of the nearest first-adjacent channel stations are shown in red. The F(50,10) 80 dBu contours of the nearest second-adjacent channel stations are shown in red. The F(50,10) 40 dBu contours of the nearest co-channel stations are shown in blue.

The second map of a group shows a dot-overlay display of the route taken by the measurement vehicle. Dots in green indicate successful IBOC reception; dots in red indicate no IBOC reception.

The third sheet of a group (except two sheets for KXPR) show the drive-test timeline (in seconds), along with the signal powers of the desired channel and upper and lower adjacent channels. The graphs also show (in dark blue) the status of IBOC reception along the routes; a binary "1" indicates successful reception and a "0" indicates no IBOC reception.

To illustrate the success of the preliminary IBOC reception model, we have added the actual result of the predictions in violet above the receiver's status. The model used only the signal power data shown on the graph at one-second intervals to determine the real-time operation of the IBOC receiver. We are pleased to report that the model is providing between 85% and 95% prediction accuracy for all stations measured, which indicates that we have developed an improved process for determining the interference-limited coverage of IBOC DAB. The next steps will be to put the model parameters into the CSPT Irregular Terrain Model to predict station coverage. We look forward to sharing those results with CPB in our next report.

Appendix A
Photos of the Station Measurement System

Figure 1 - Measurement vehicle in California with calibrated groundplane antenna in place.

Figure 2 - Design of groundplane antenna system, showing 'pie' segments and calibrated monopole.

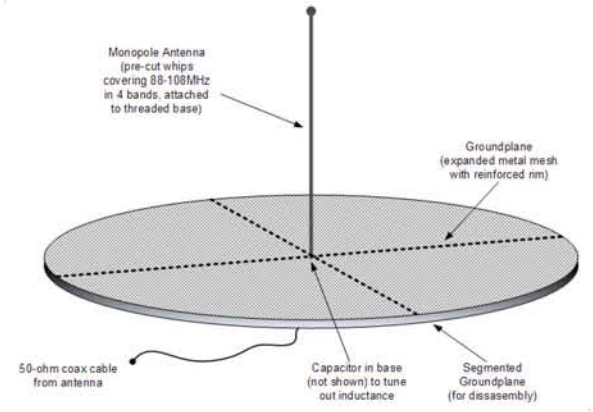


Figure 3 - Main logger with IBOC receiver atop secondary unit with signal level receivers.

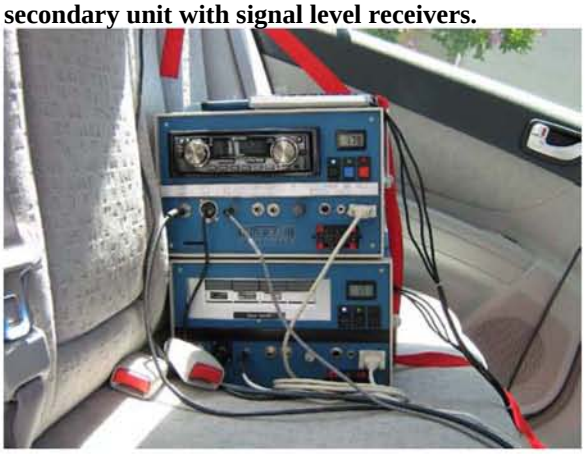
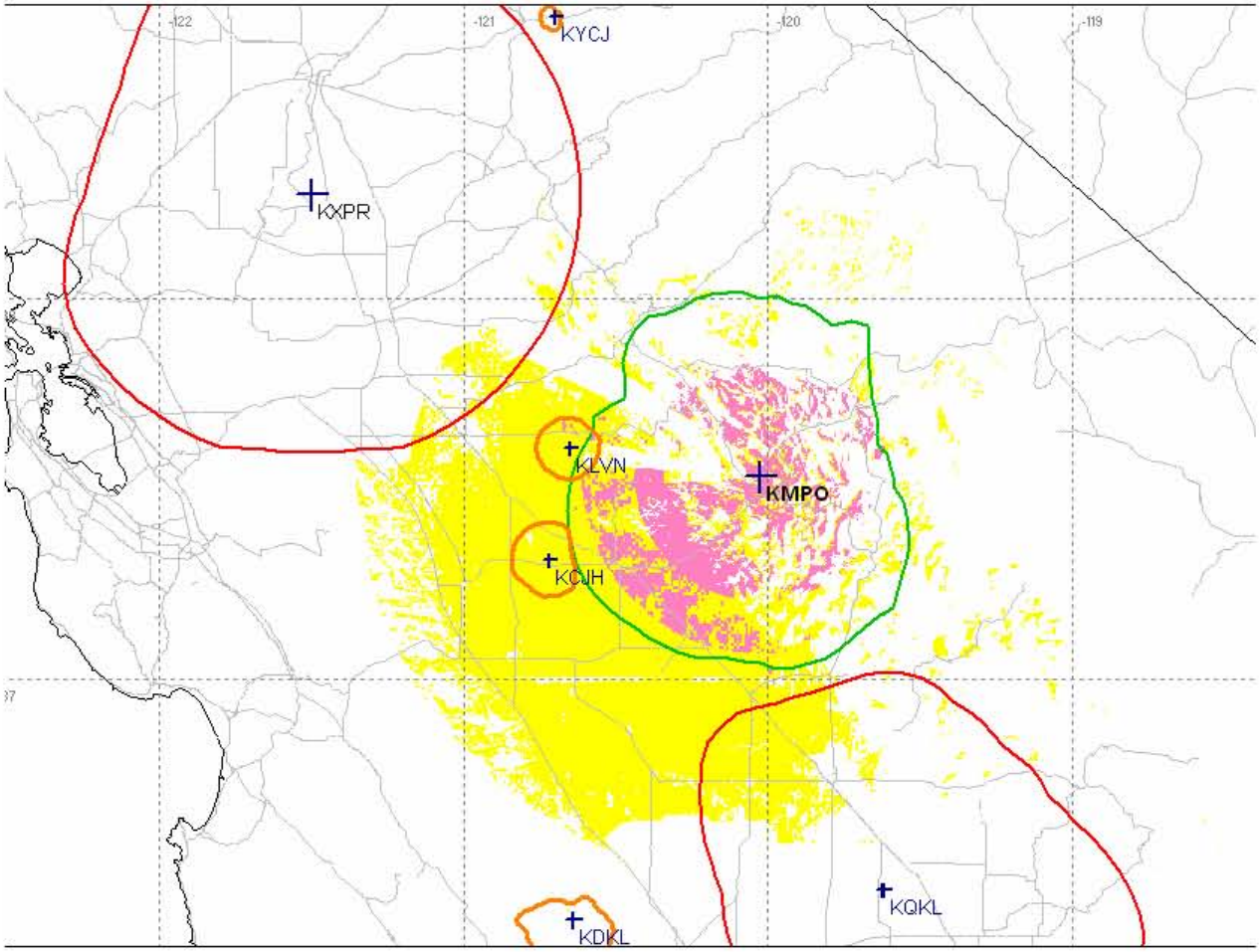


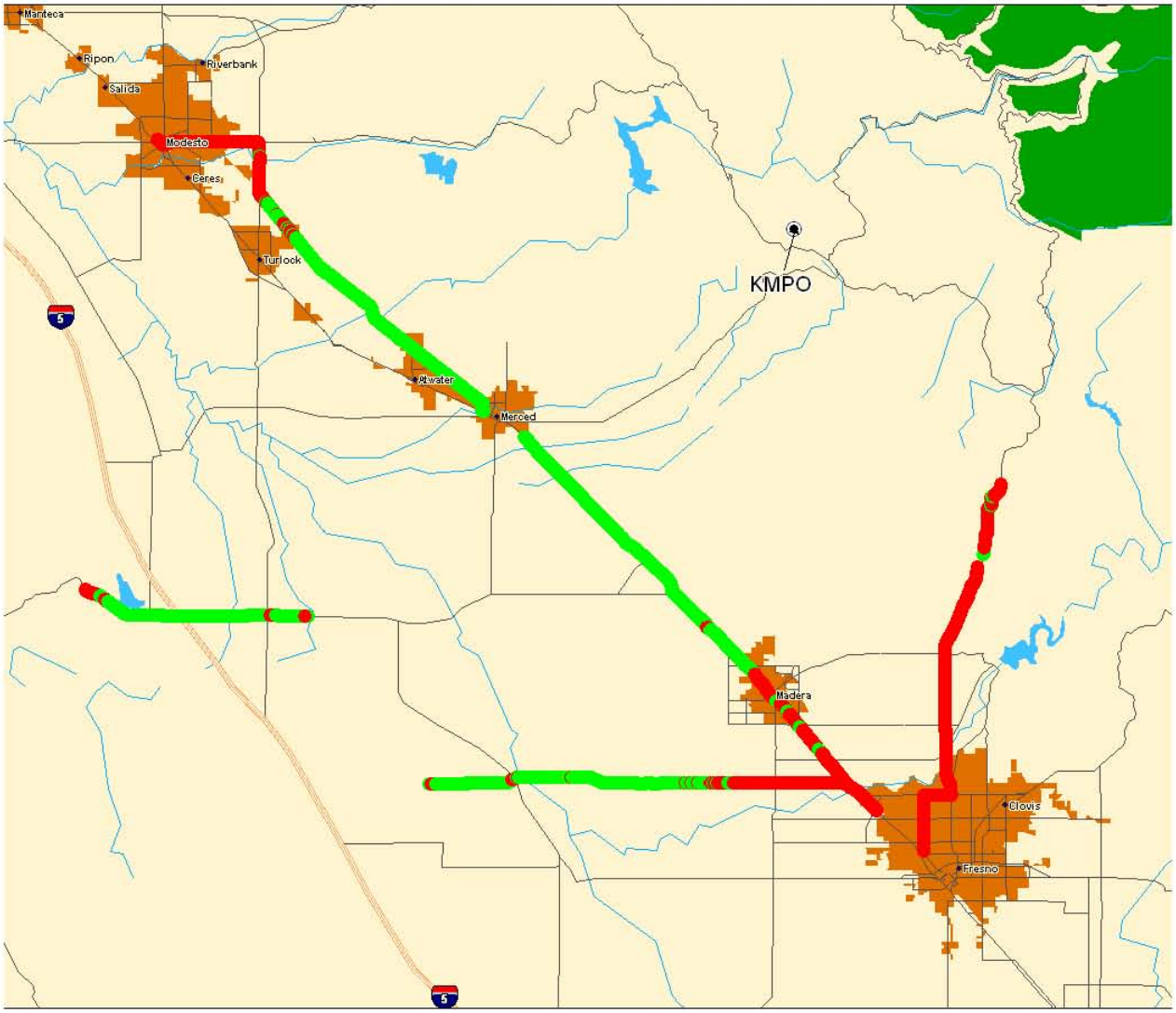
Figure 4 - Closeup of controllers tuned to desired (top), upper-adjacent channel (mid) and lower adjacent channel (bottom).

Appendix B – Station Contour Maps and Measurement Maps

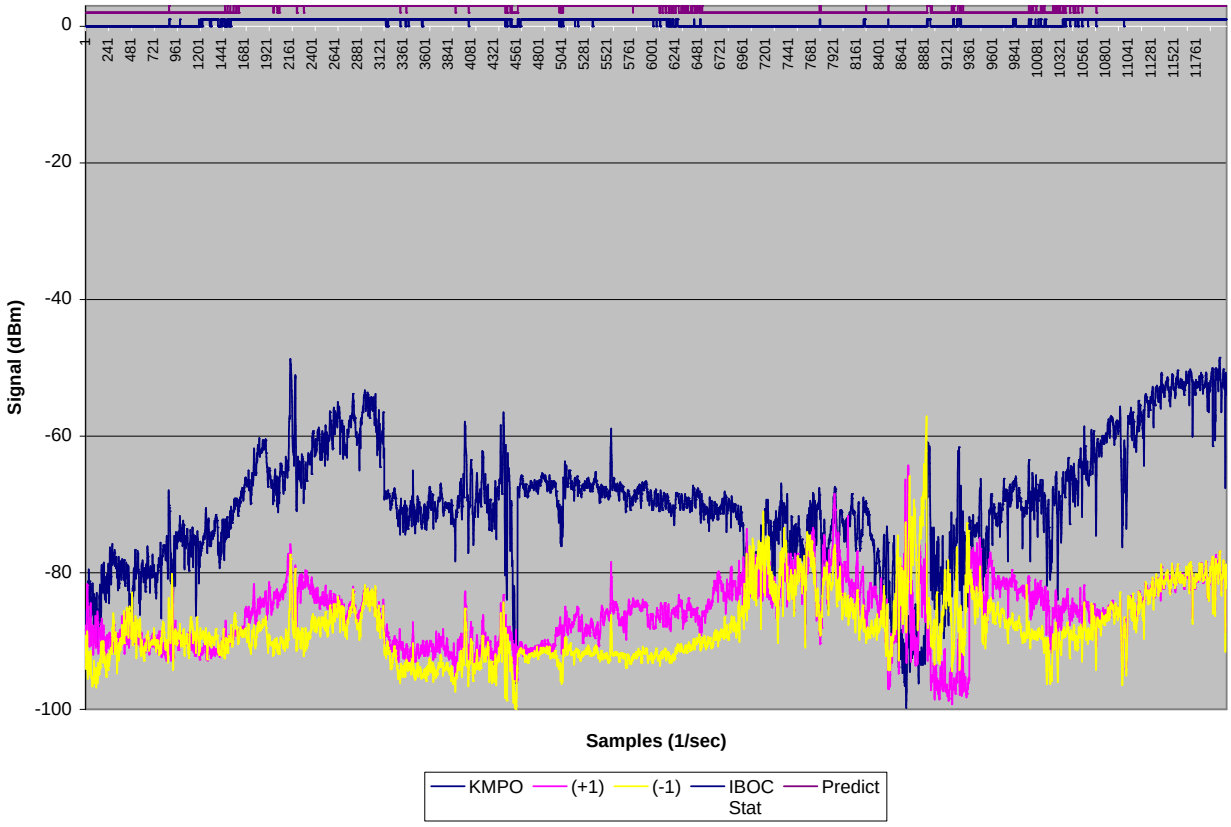
KMPO, Modesto, California
Ch. 204B, 2.05 kW, 622 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



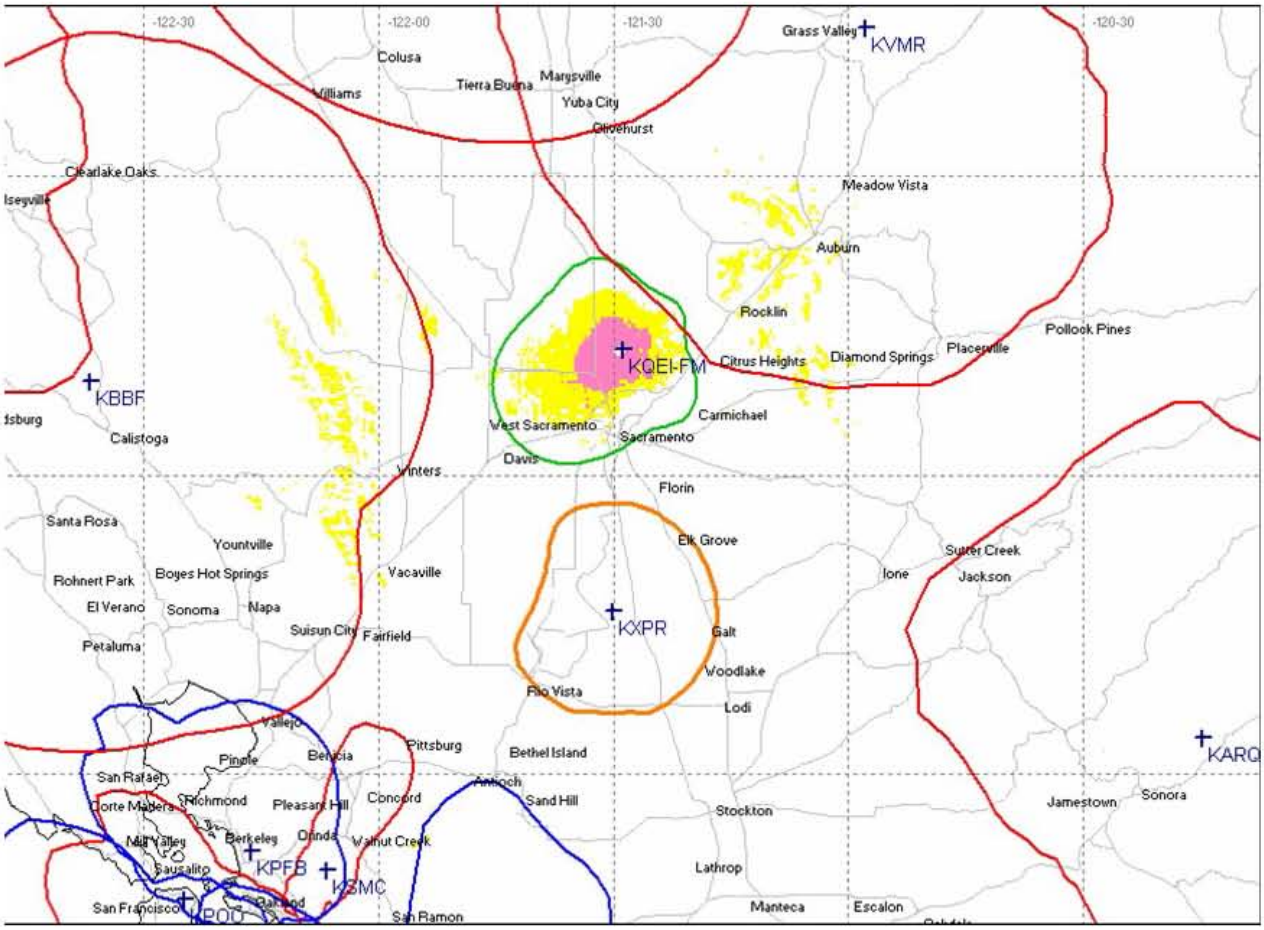
KMPO, Modesto, California
Route Map with IBOC DAB Receive Status



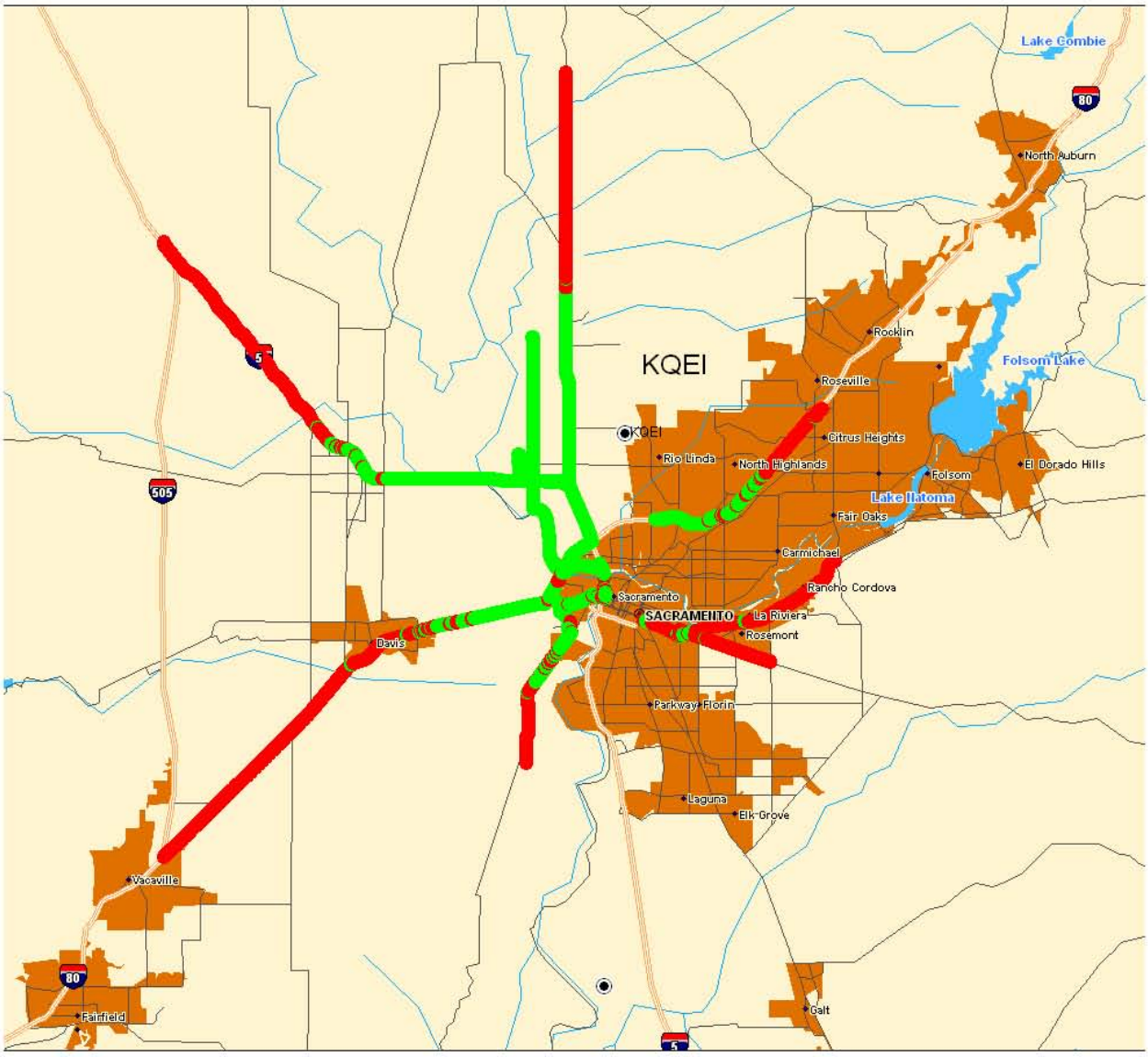
KMPO, Modesto, California
Drive-test Signal Measurements



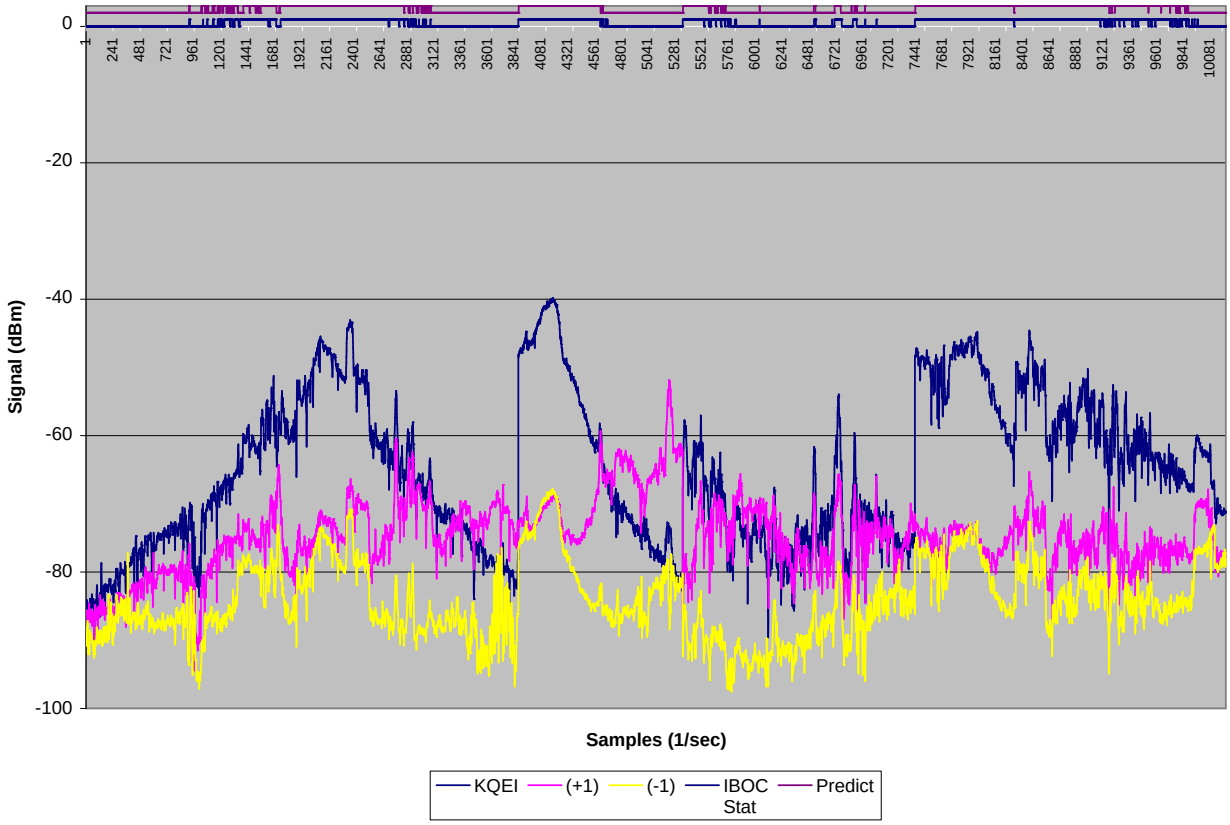
KQEI-FM, North Highlands, California
Ch. 207A, 3.1 kW, 108 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



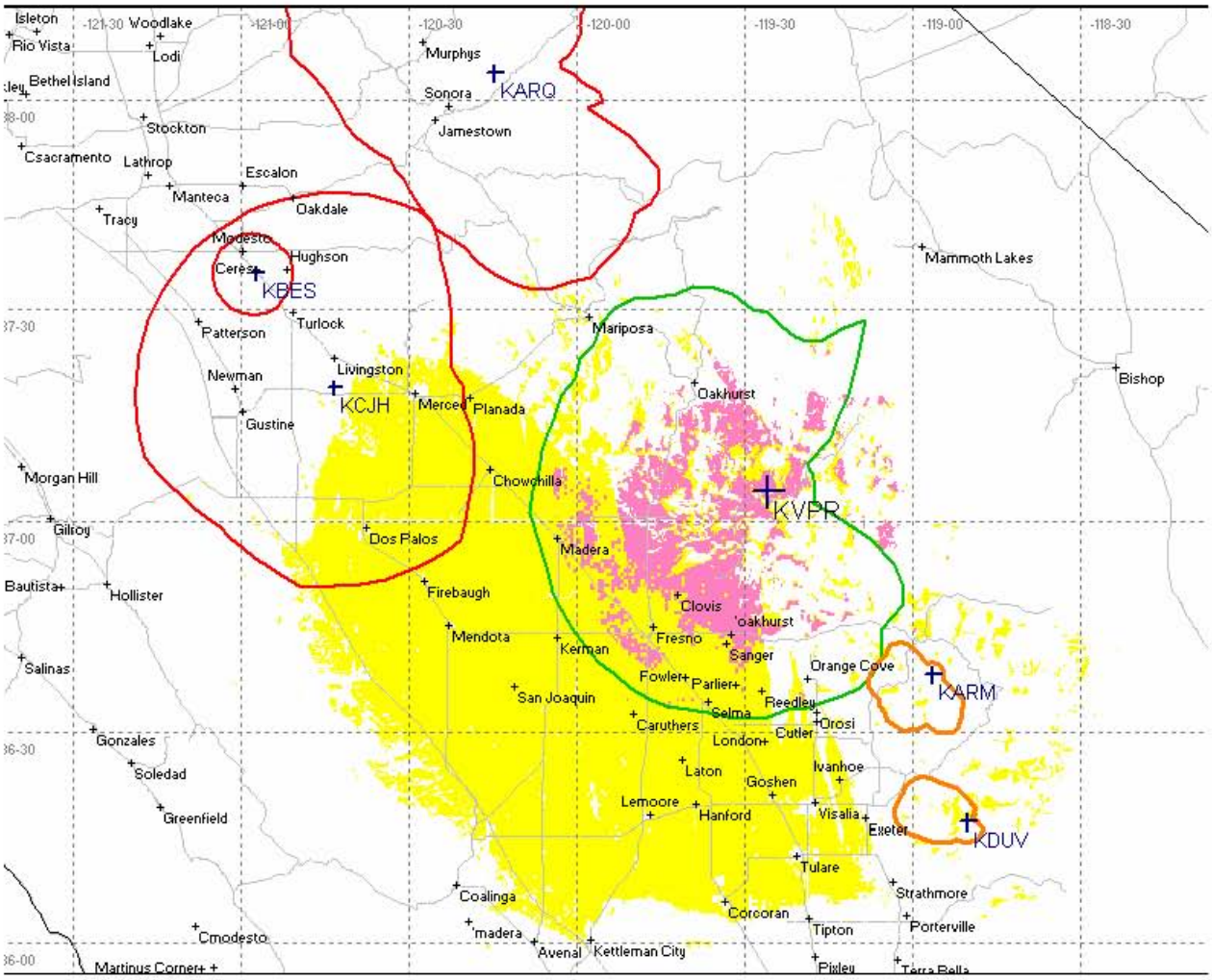
KQEI-FM, North Highlands, California
Route Map with IBOC DAB Receive Status



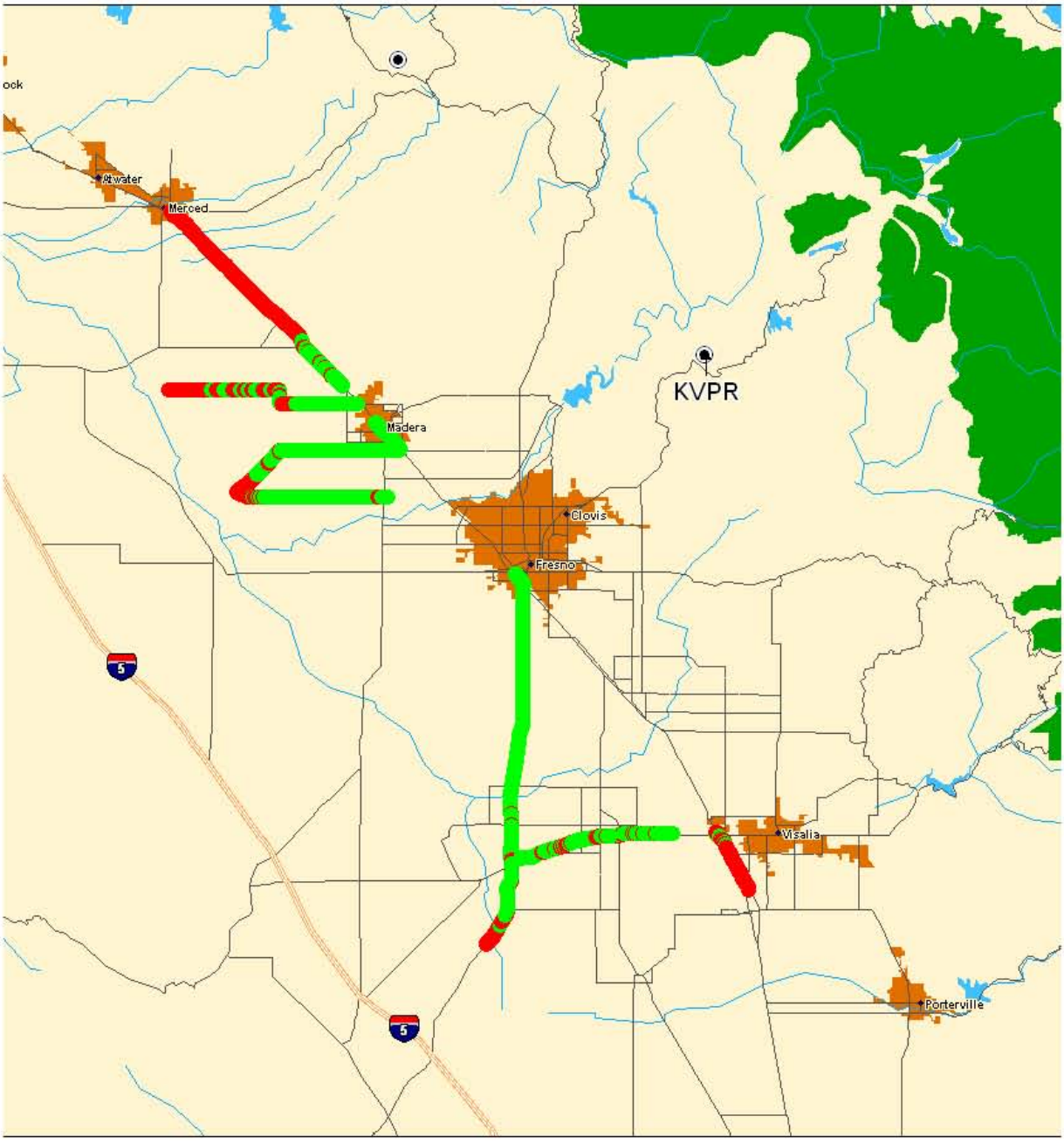
KQEI-FM, North Highlands, California
Drive-test Signal Measurements



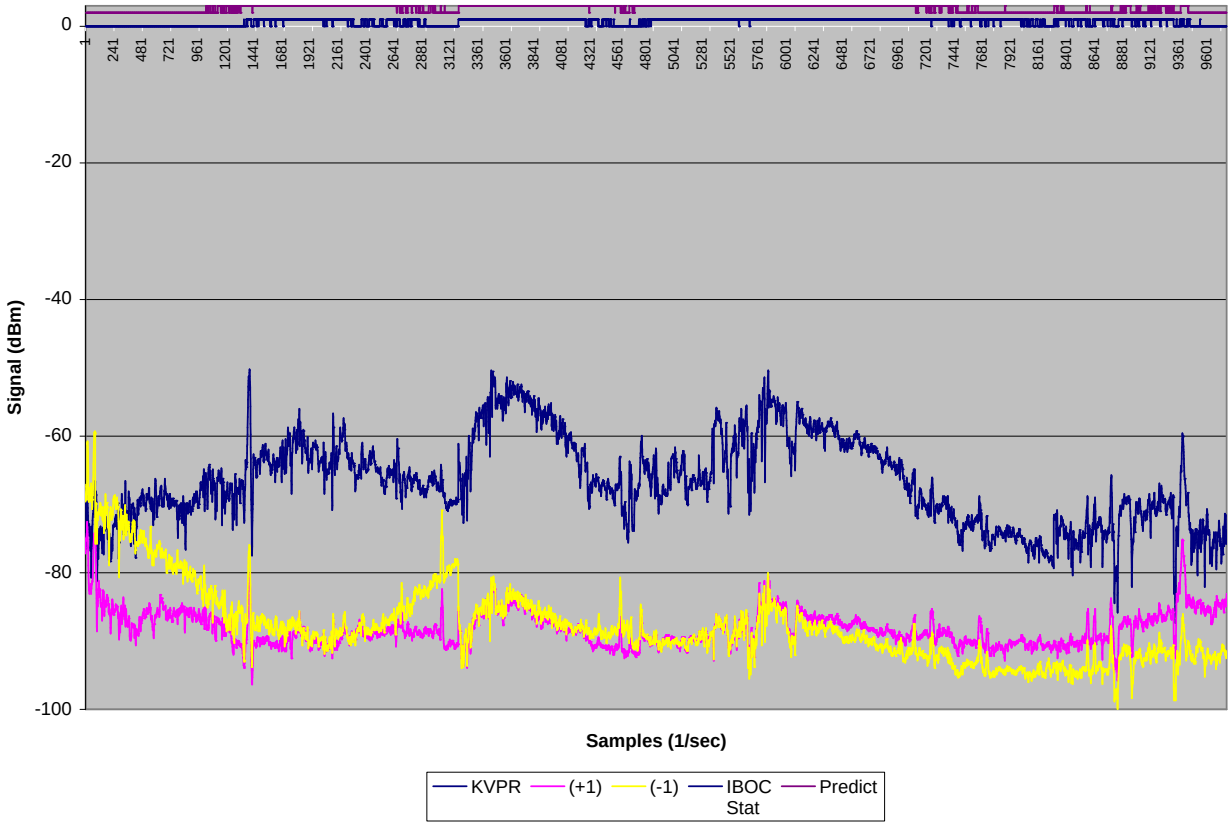
KVPR, Fresno, California
Ch. 207B, 2.45 kW, 576 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



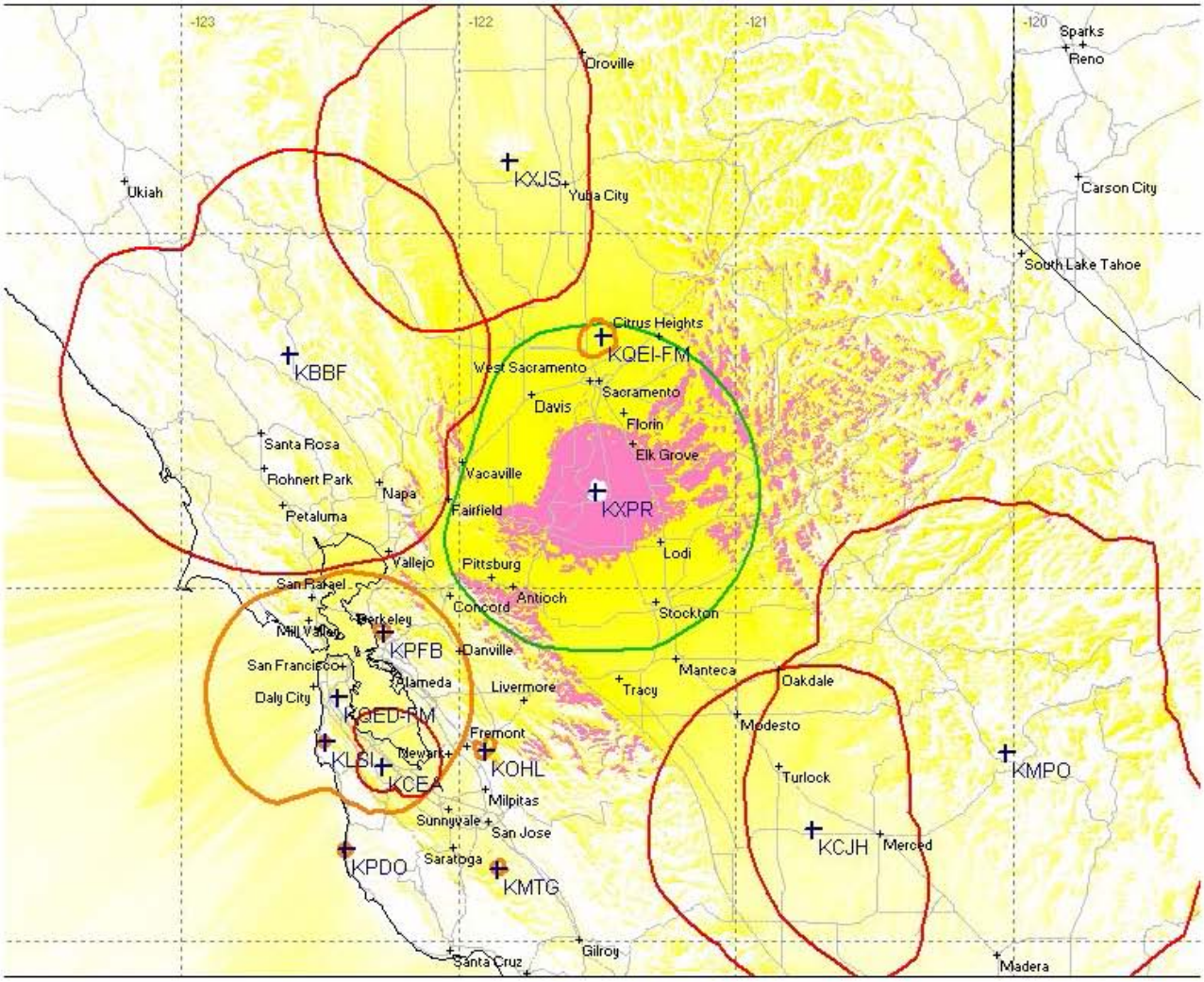
KVPR, Fresno, California
Route Map with IBOC DAB Receive Status



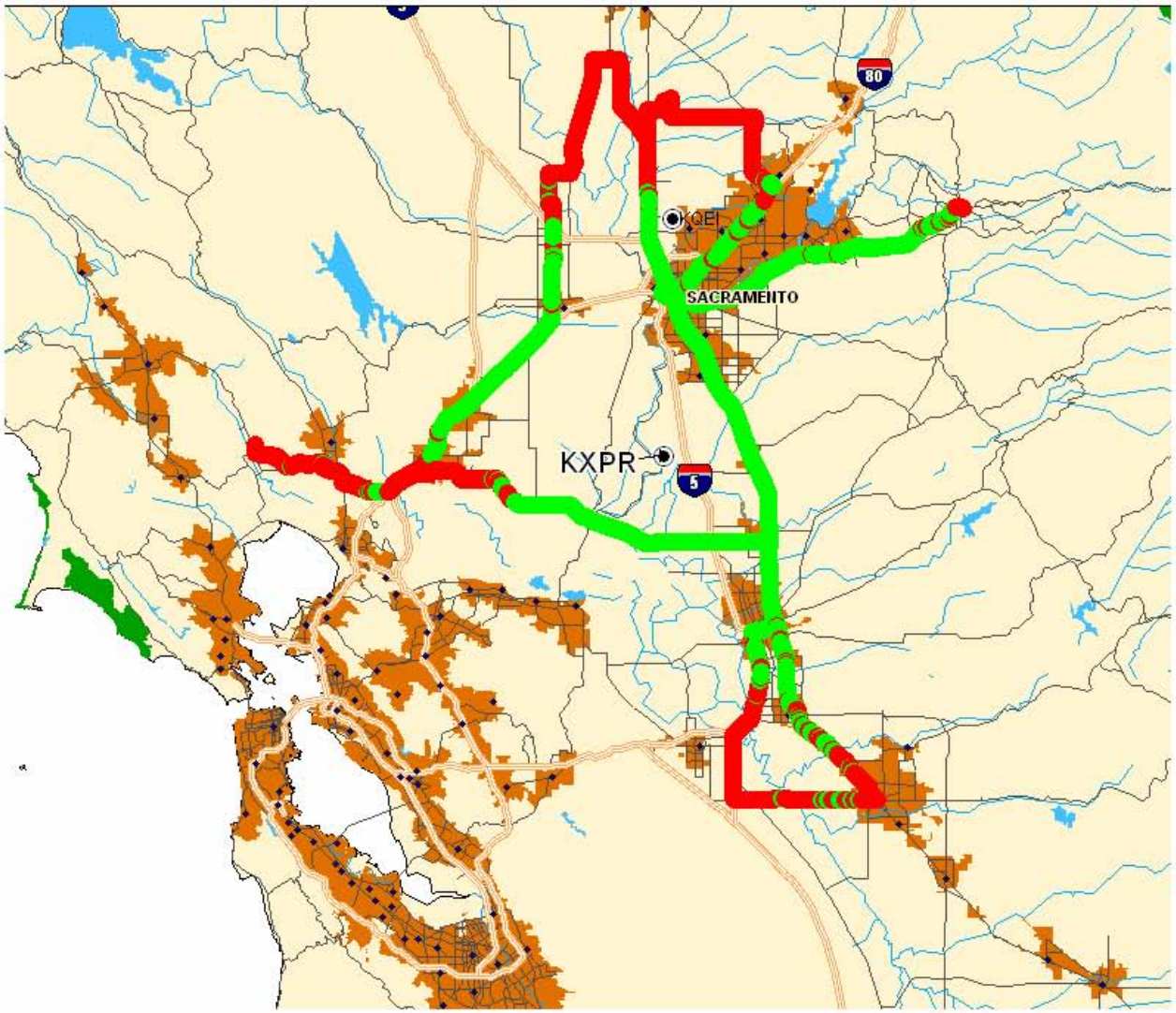
KVPR, Fresno, California
Drive-test Signal Measurements



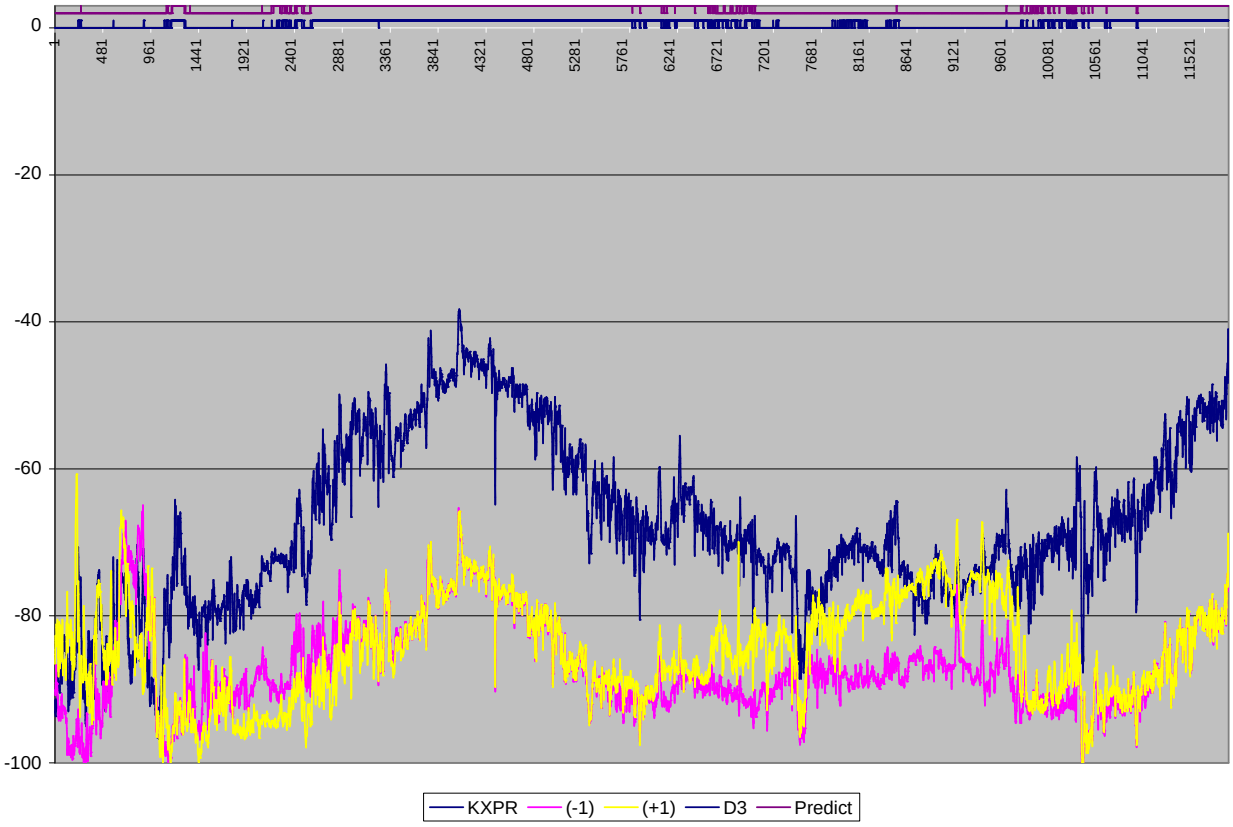
KXPR, Sacramento, California
Ch. 205B, 50 kW, 150 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



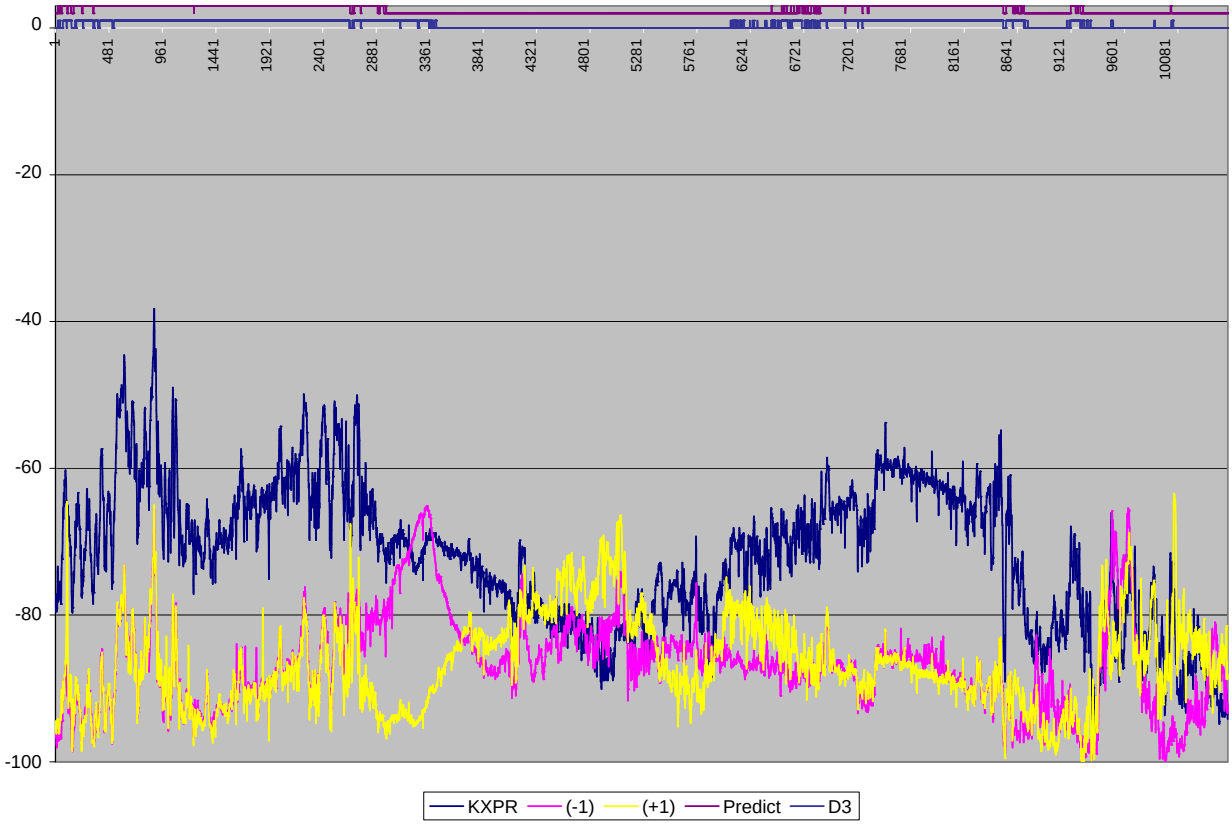
KXPR, Sacramento, California
Route Map with IBOC DAB Receive Status



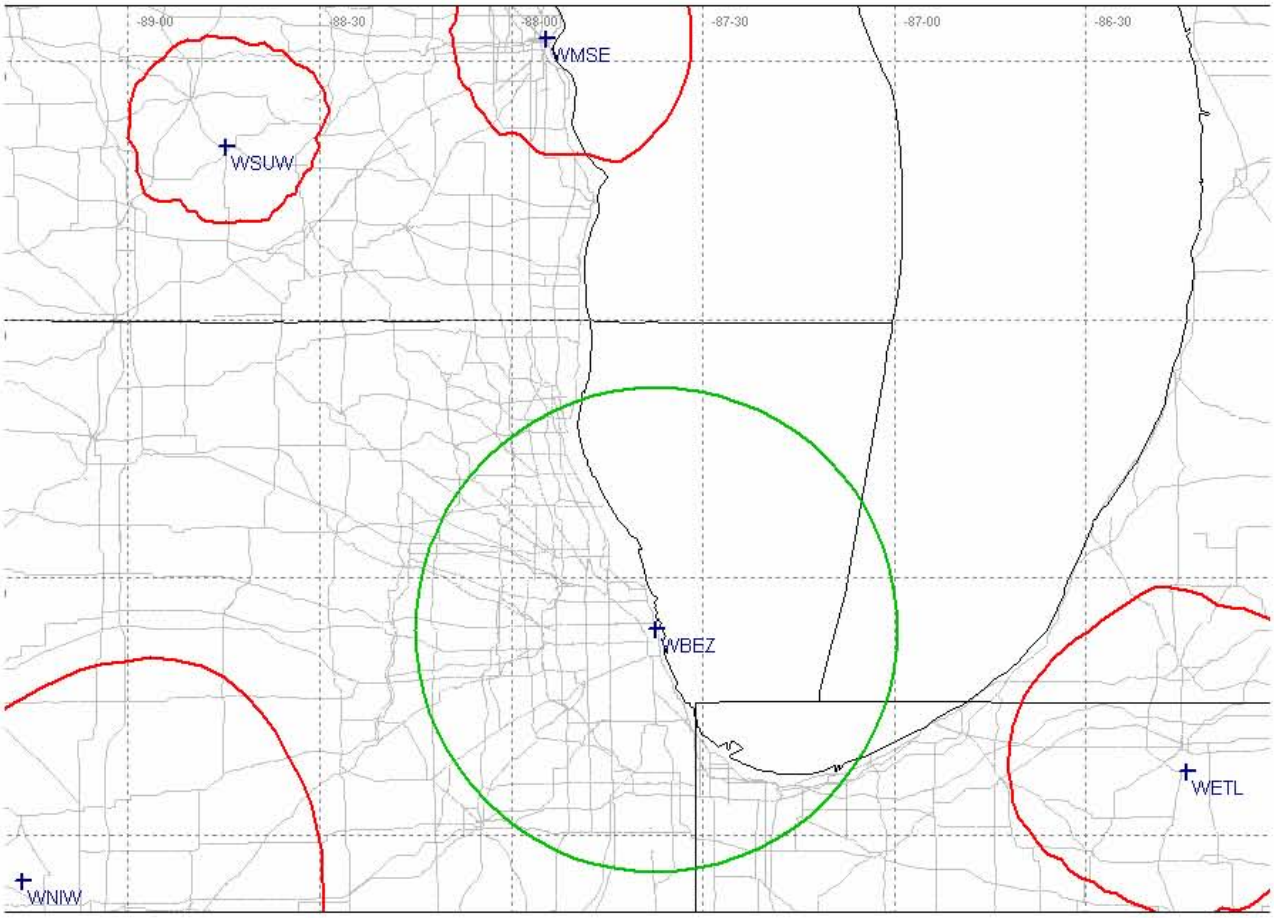
KXPR, Sacramento, California
Drive-test Signal Measurements (1 of 2)



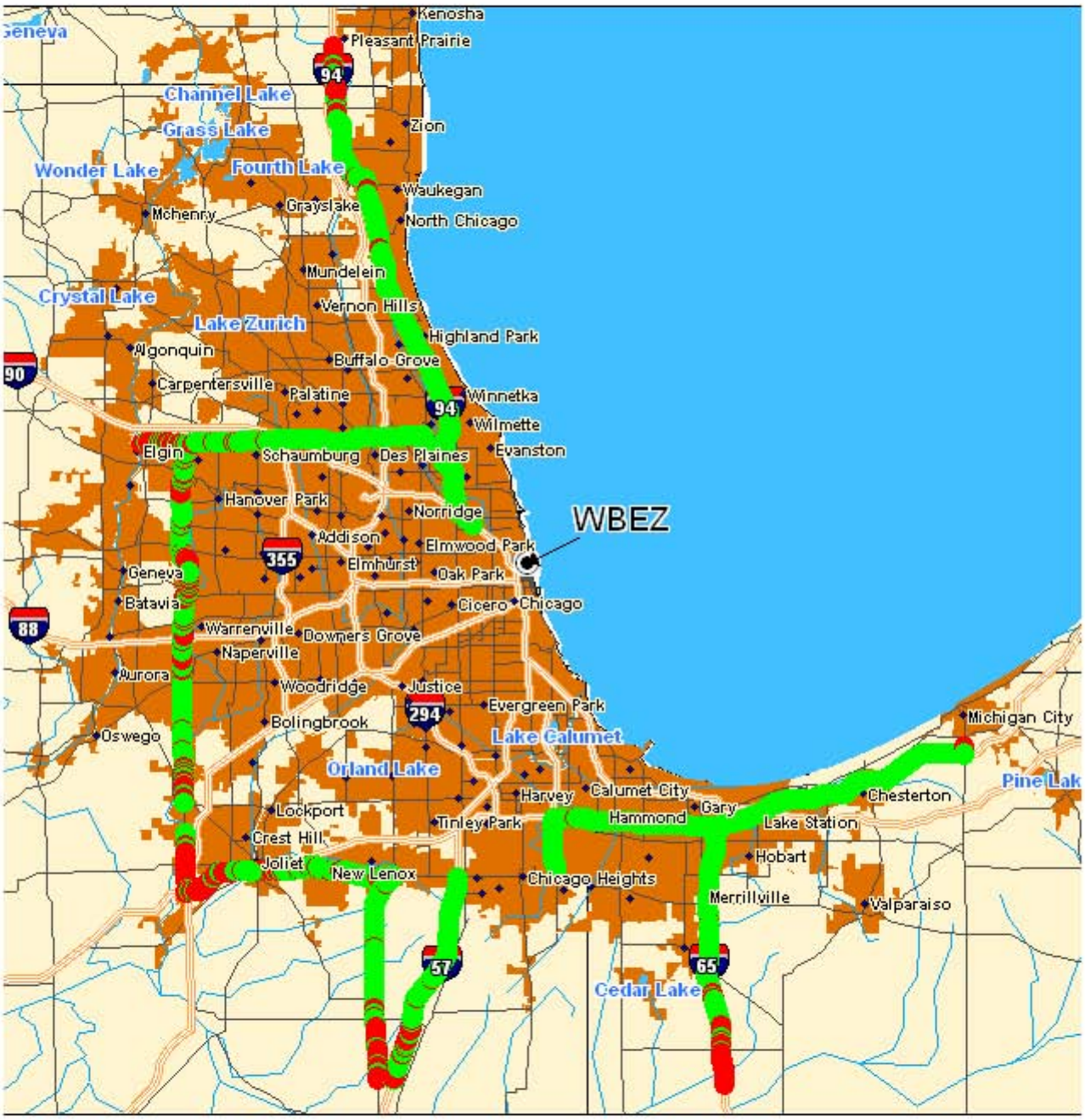
KXPR, Sacramento, California
Drive-test Signal Measurements (2 of 2)



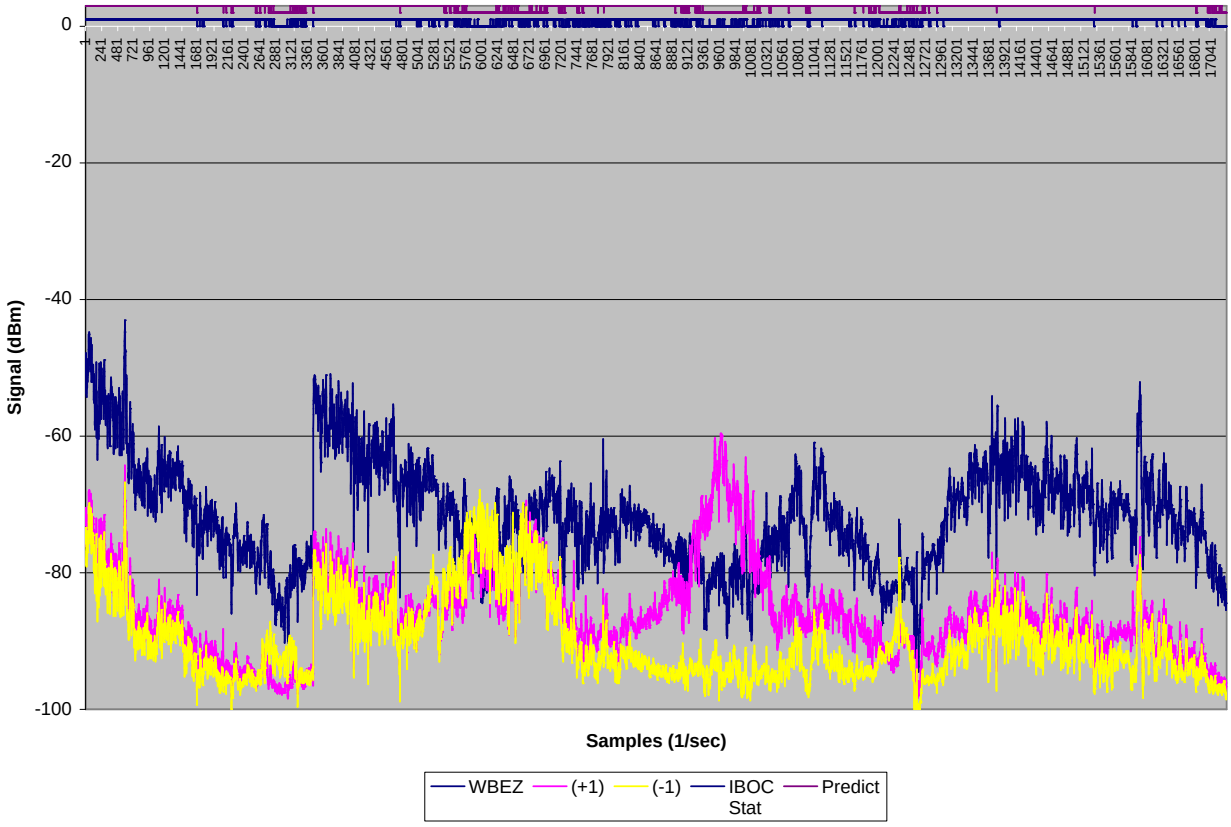
WBEZ, Chicago, Illinois
Ch. 218B, 8.3 kW, 360 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



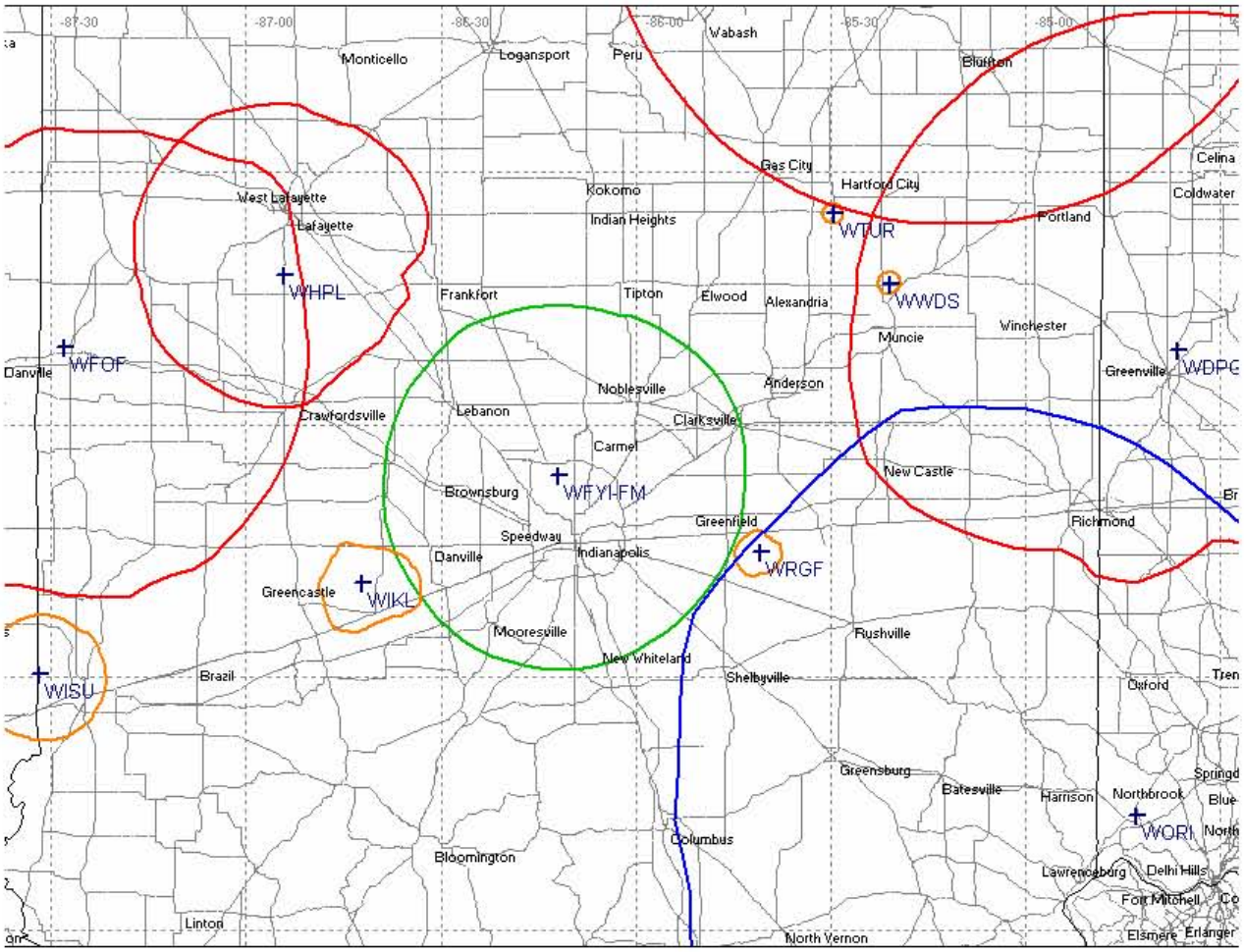
WBEZ, Chicago, Illinois
Route Map with IBOC DAB Receive Status



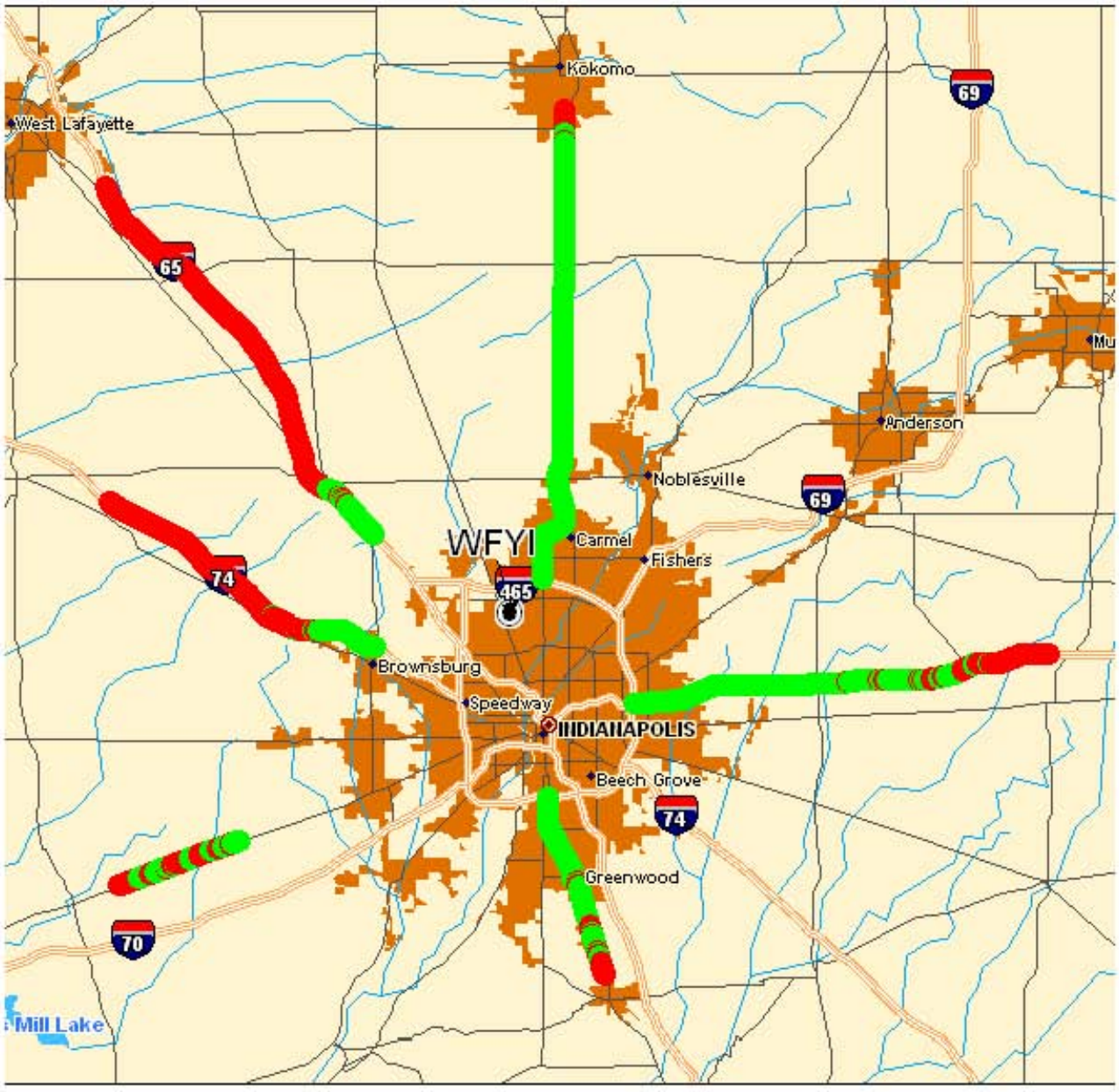
WBEZ, Chicago, Illinois
Drive-test Signal Measurements



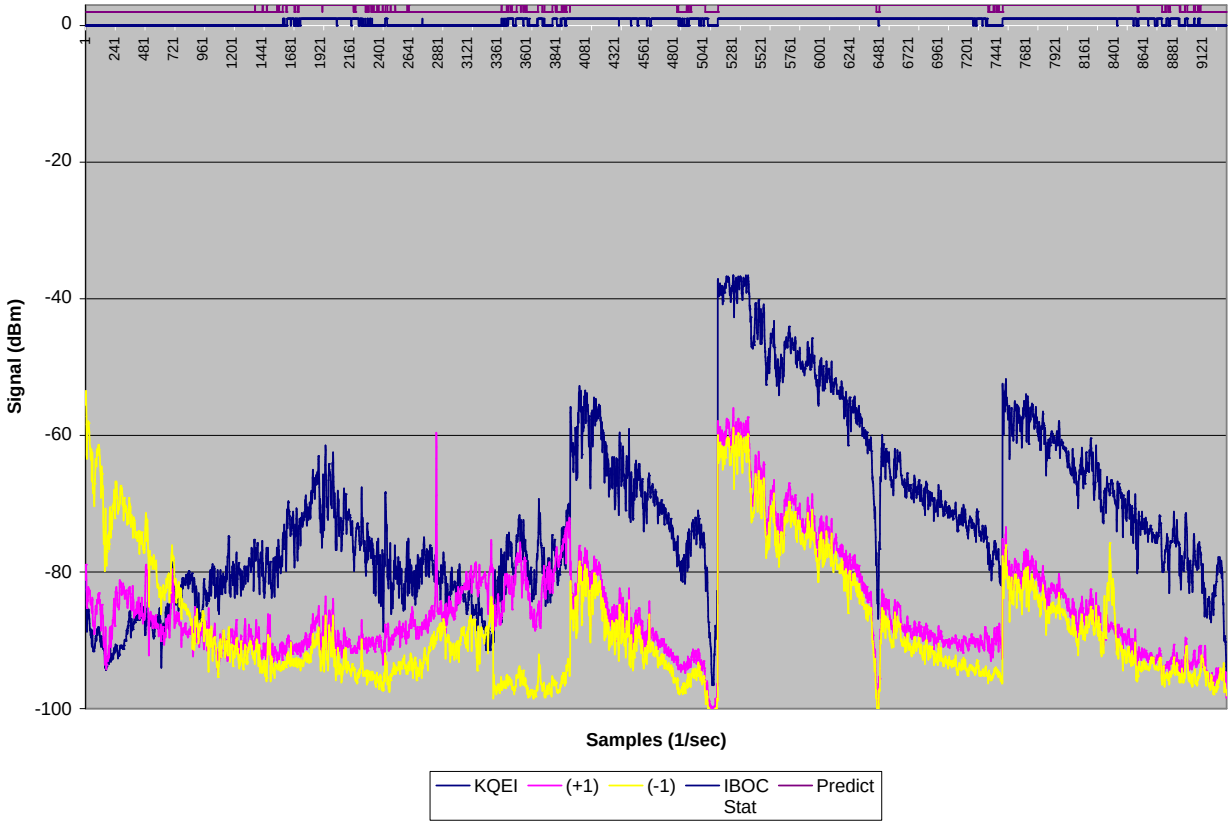
WFYI-FM, Indianapolis, Indiana
Ch. 211B, 10 kW, 171 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



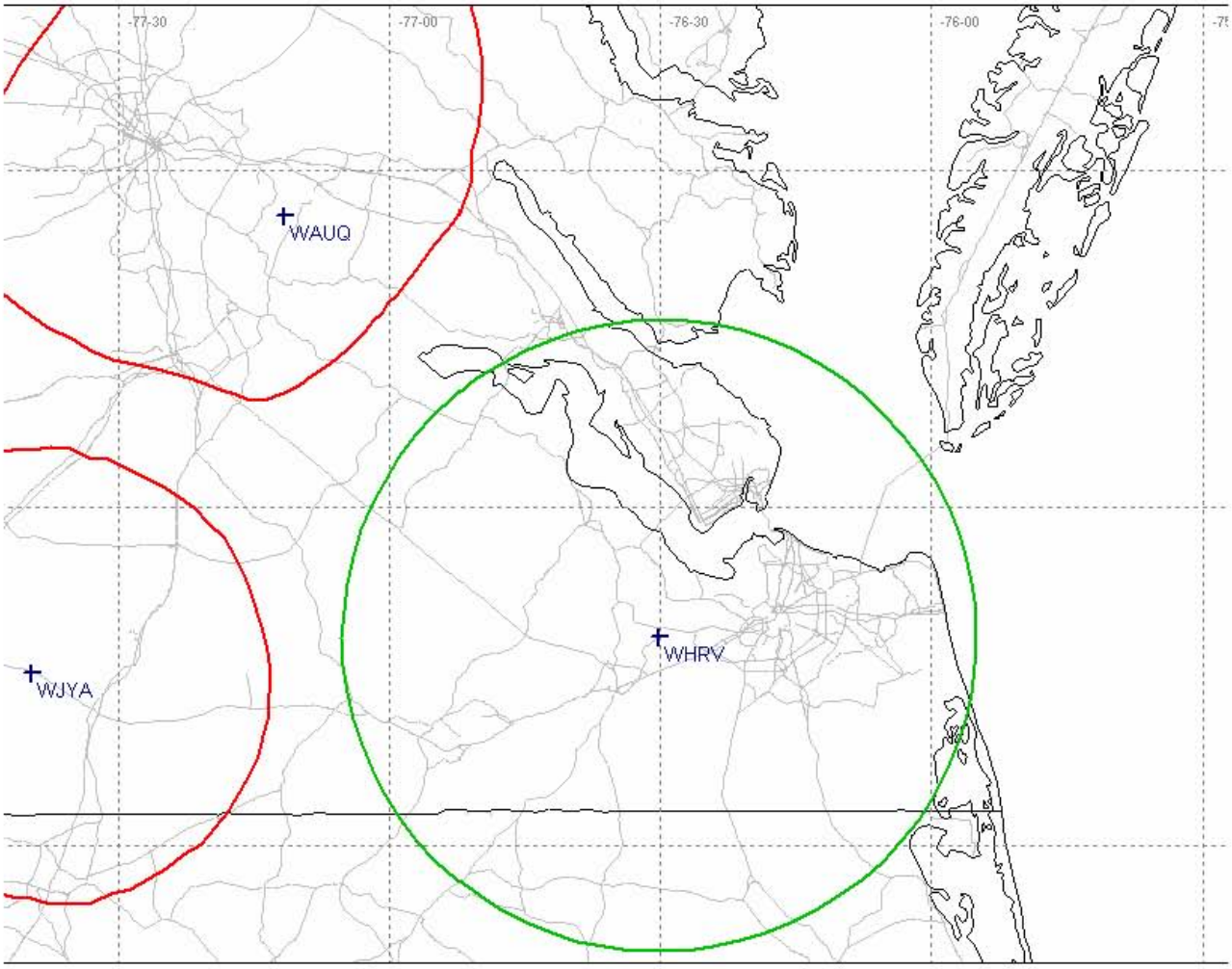
WFYI-FM, Indianapolis, Indiana
Route Map with IBOC DAB Receive Status



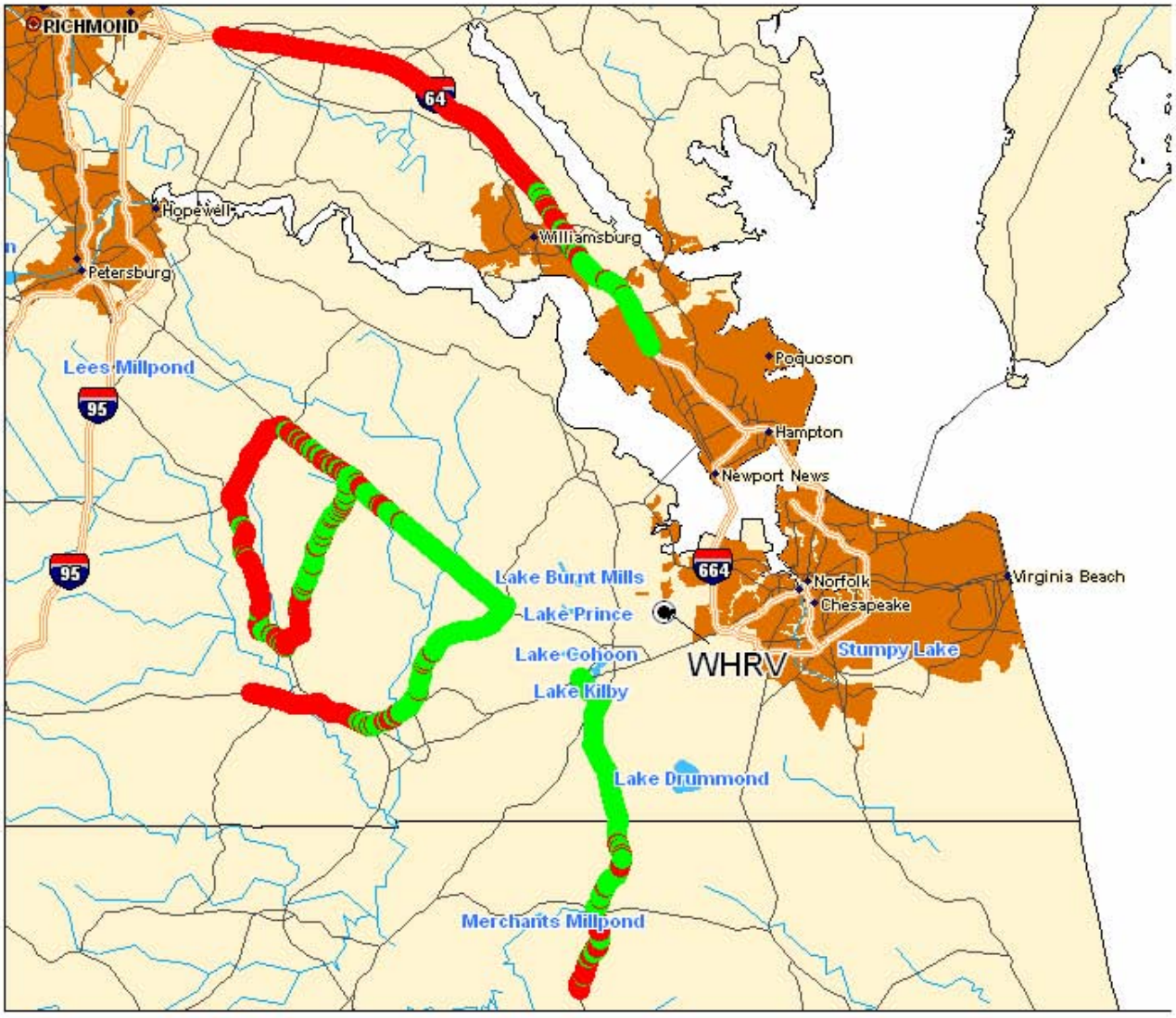
WFYI-FM, Indianapolis, Indiana
Drive-test Signal Measurements



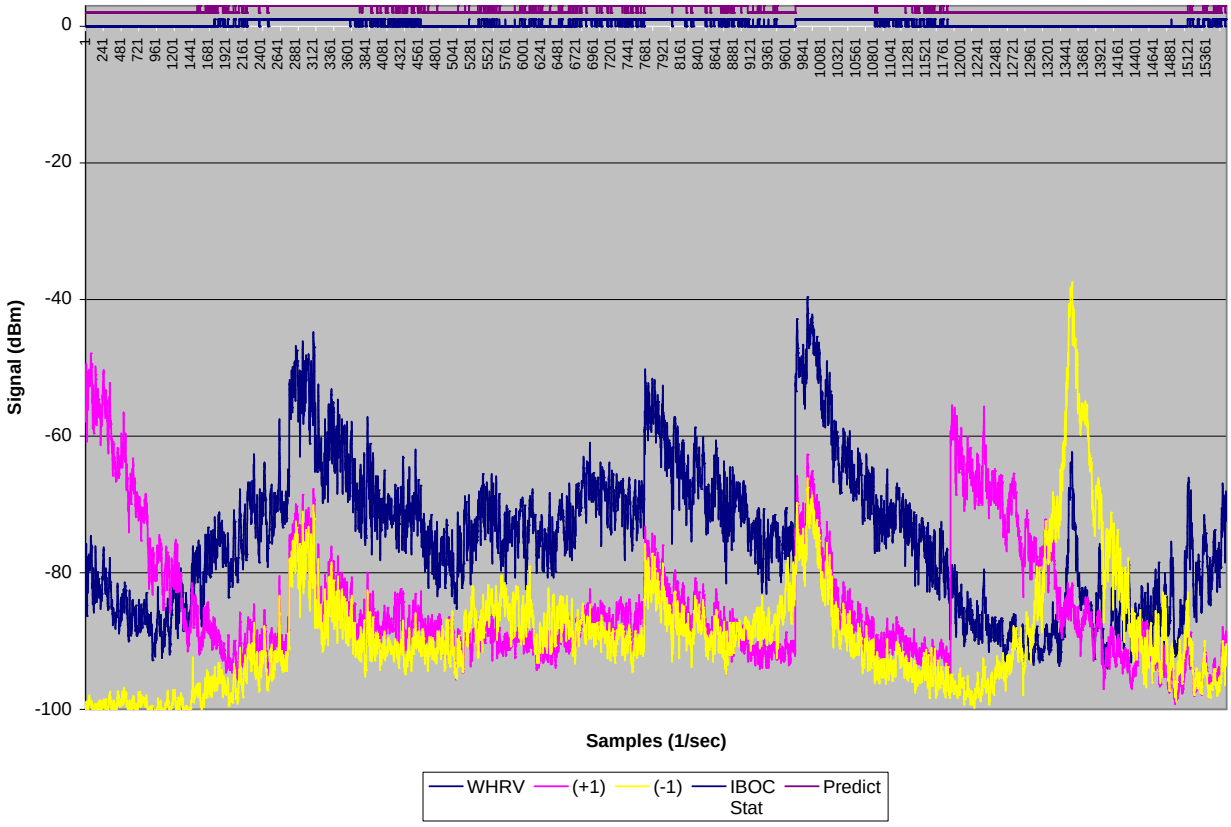
WHRV, Norfolk, Virginia
Ch. 208B, 8.8 kW, 350 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



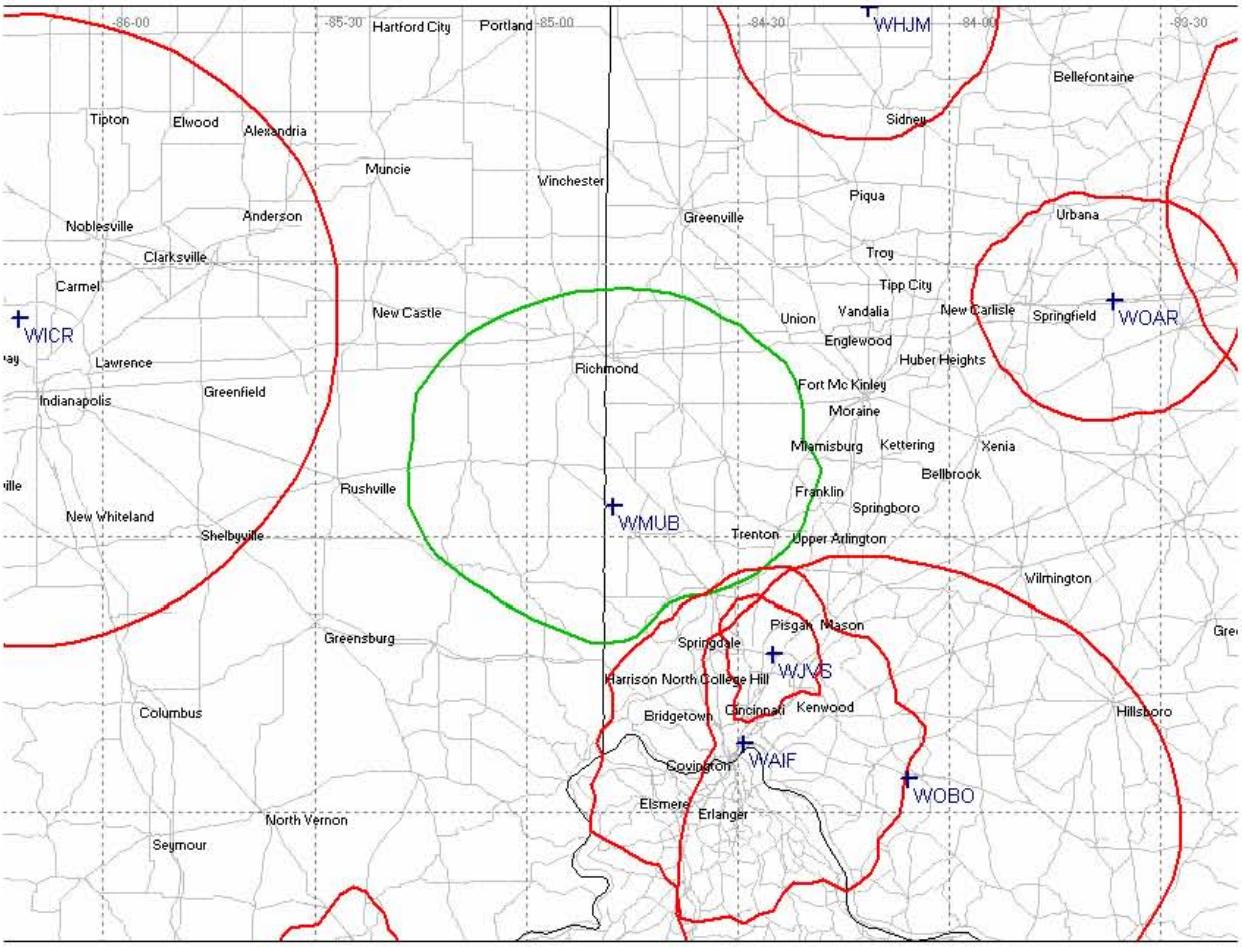
WHRV, Norfolk, Virginia
Route Map with IBOC DAB Receive Status



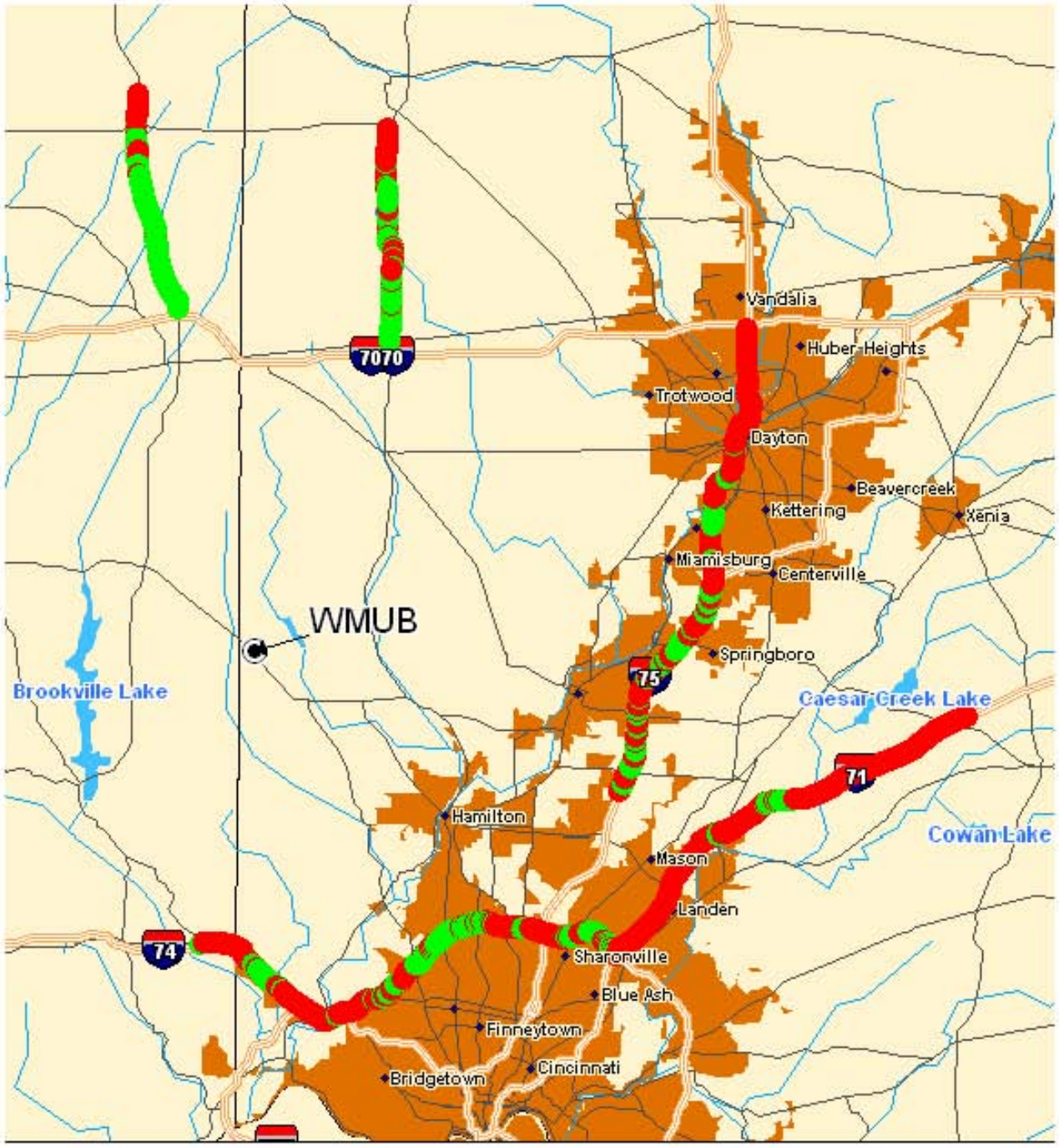
WHRV, Norfolk, Virginia
Drive-test Signal Measurements



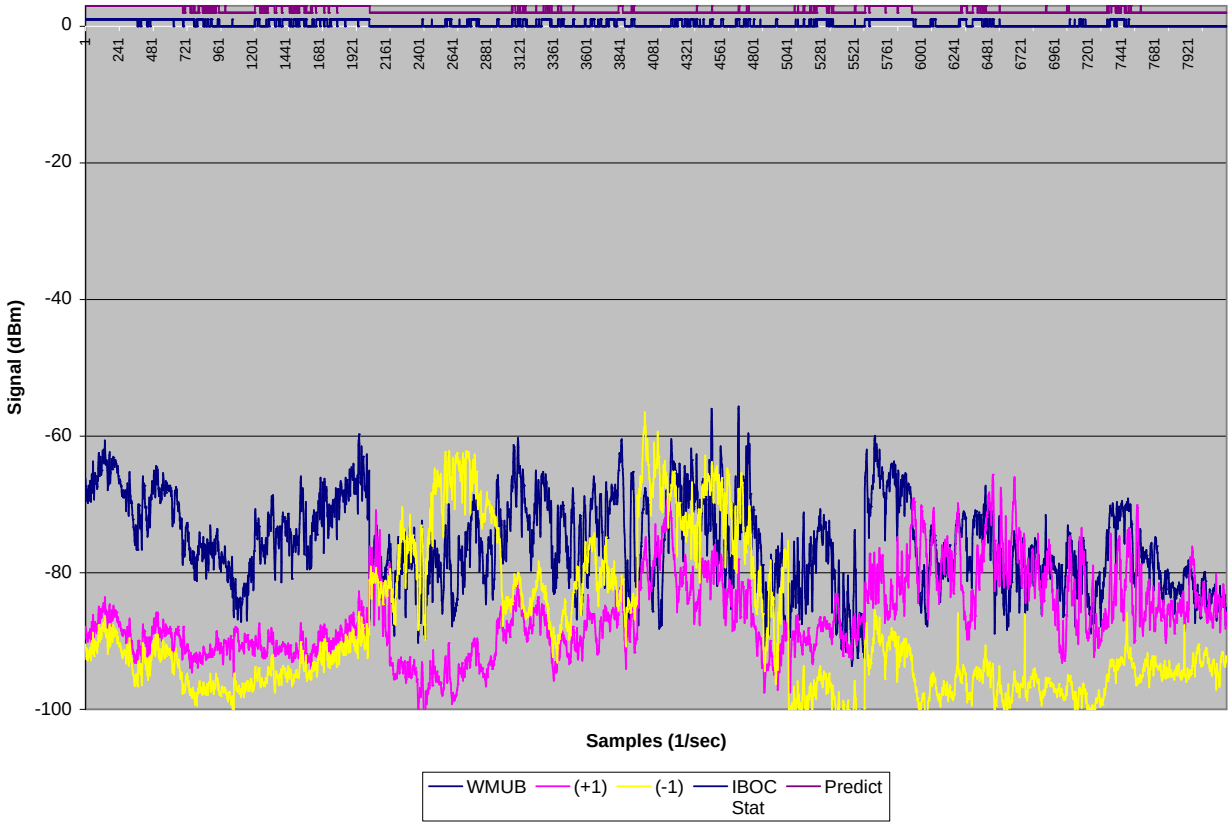
WMUB, Oxford, Ohio
Ch. 203B, 24.5 kW, 147 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



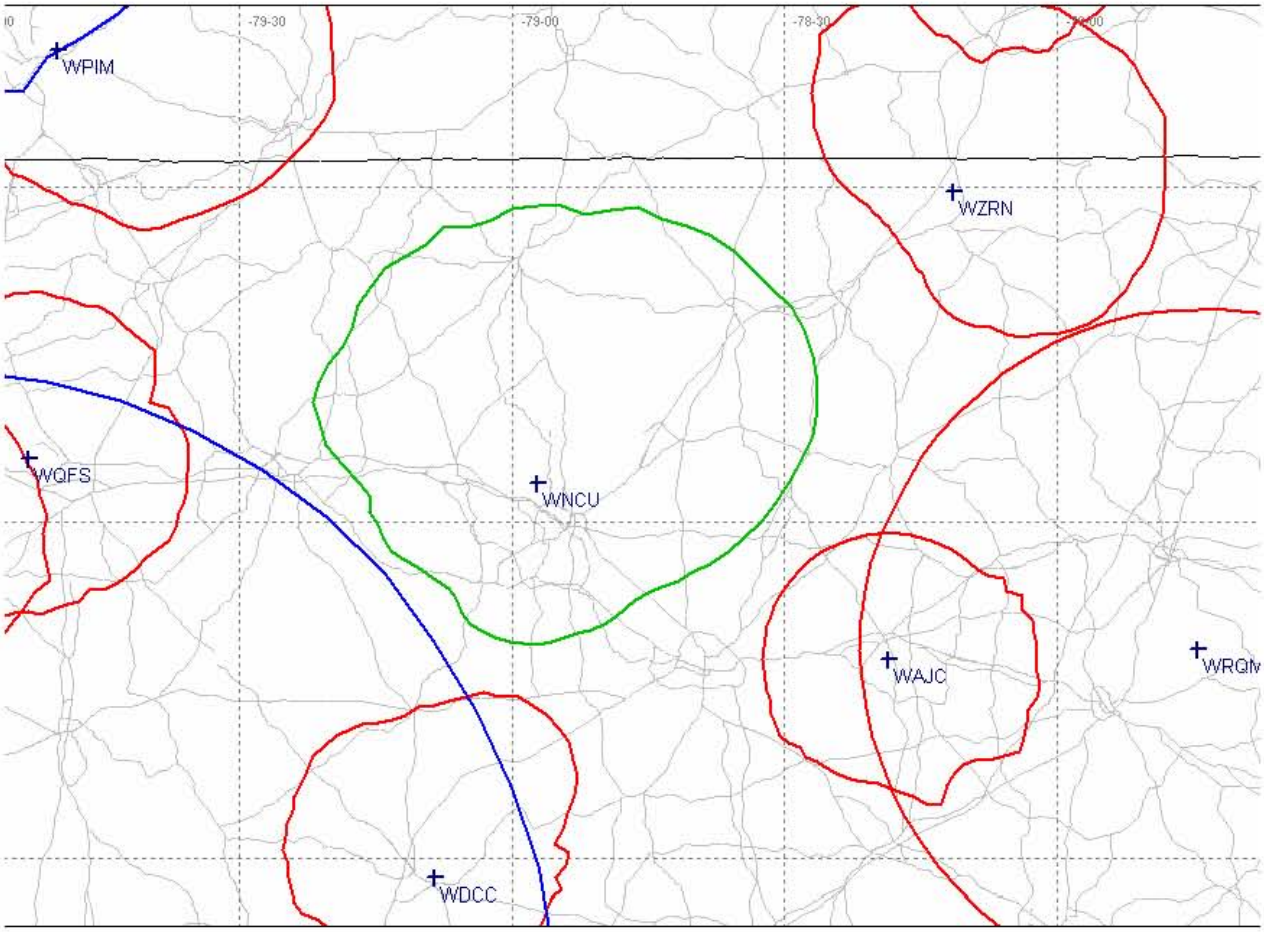
WMUB, Oxford, Ohio
Route Map with IBOC DAB Receive Status



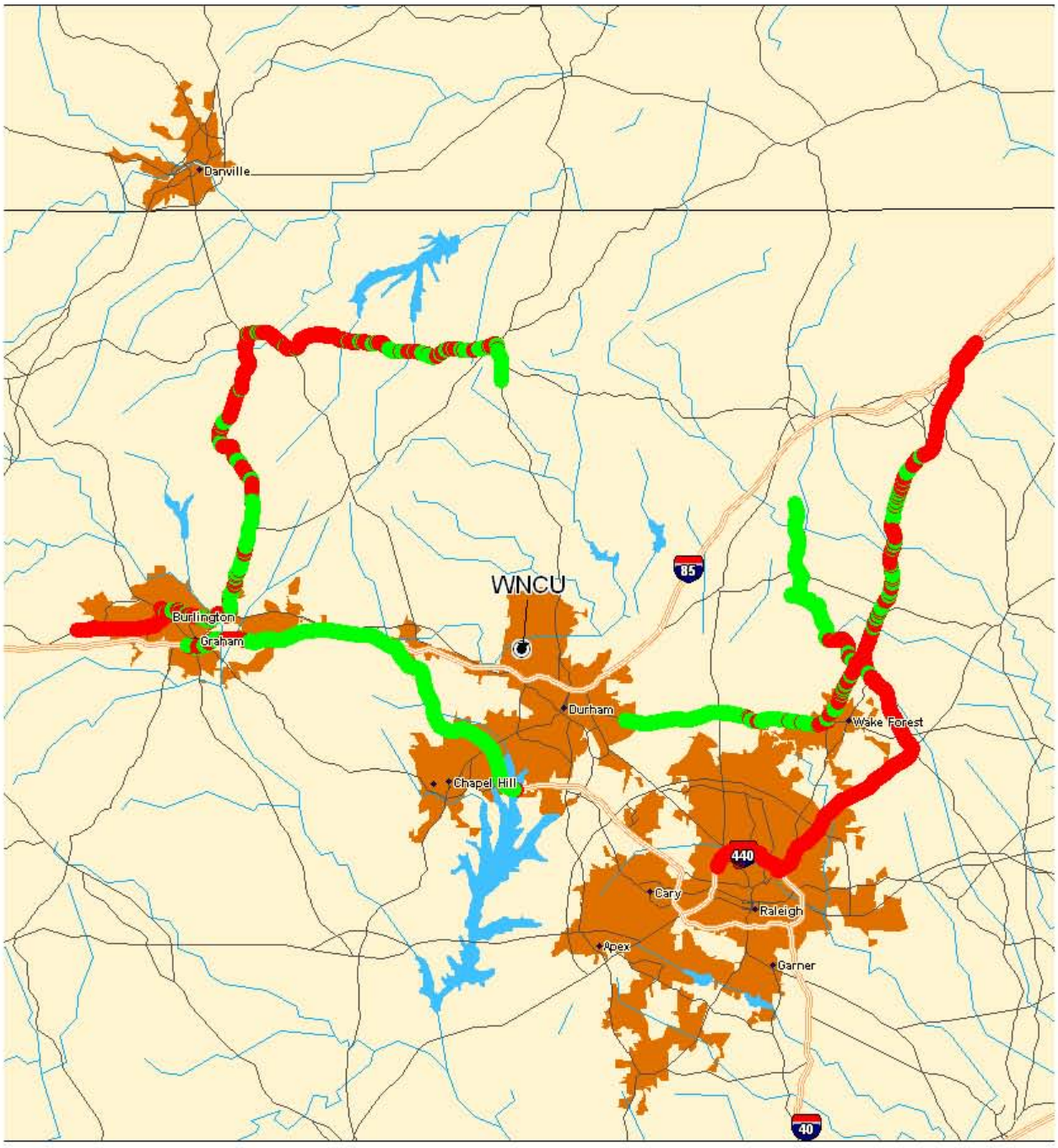
WMUB, Oxford, Ohio
Drive-test Signal Measurements



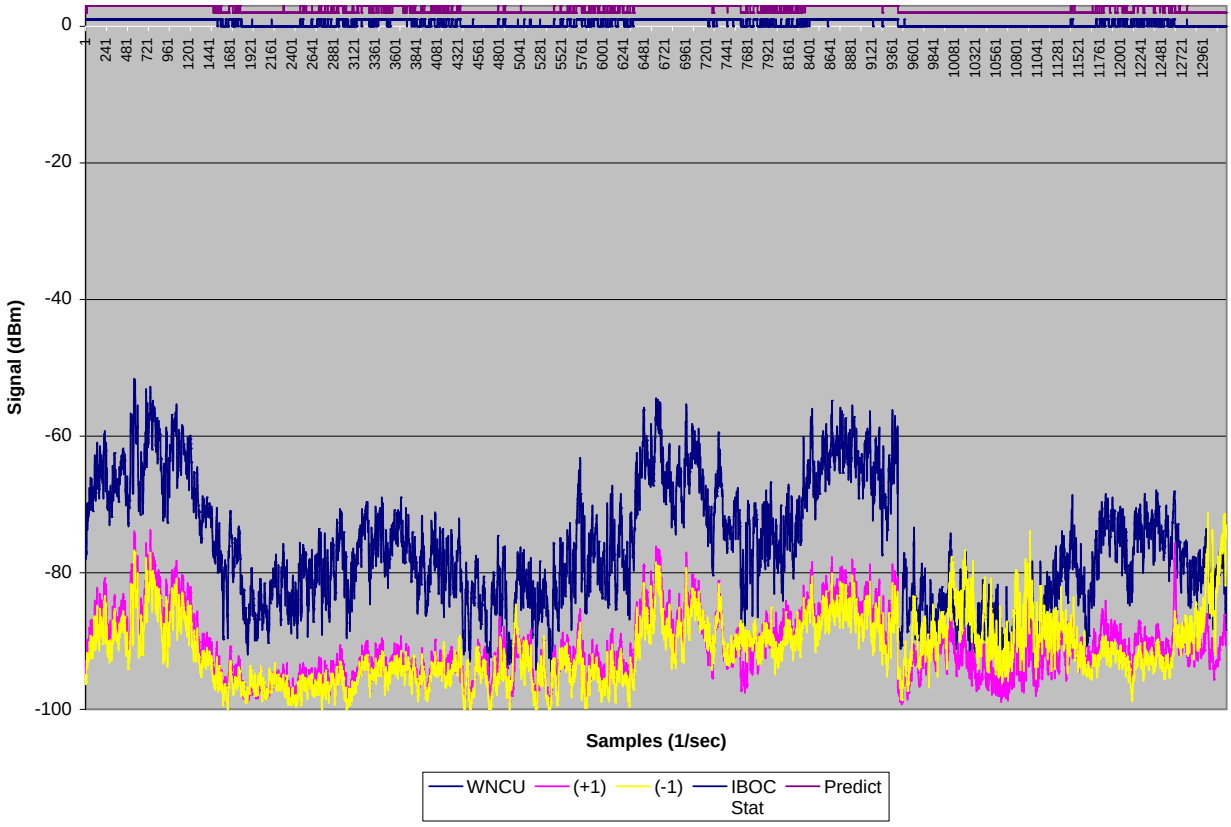
WNCU, Durham, North Carolina
Ch. 214C2, 50 kW, 132 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



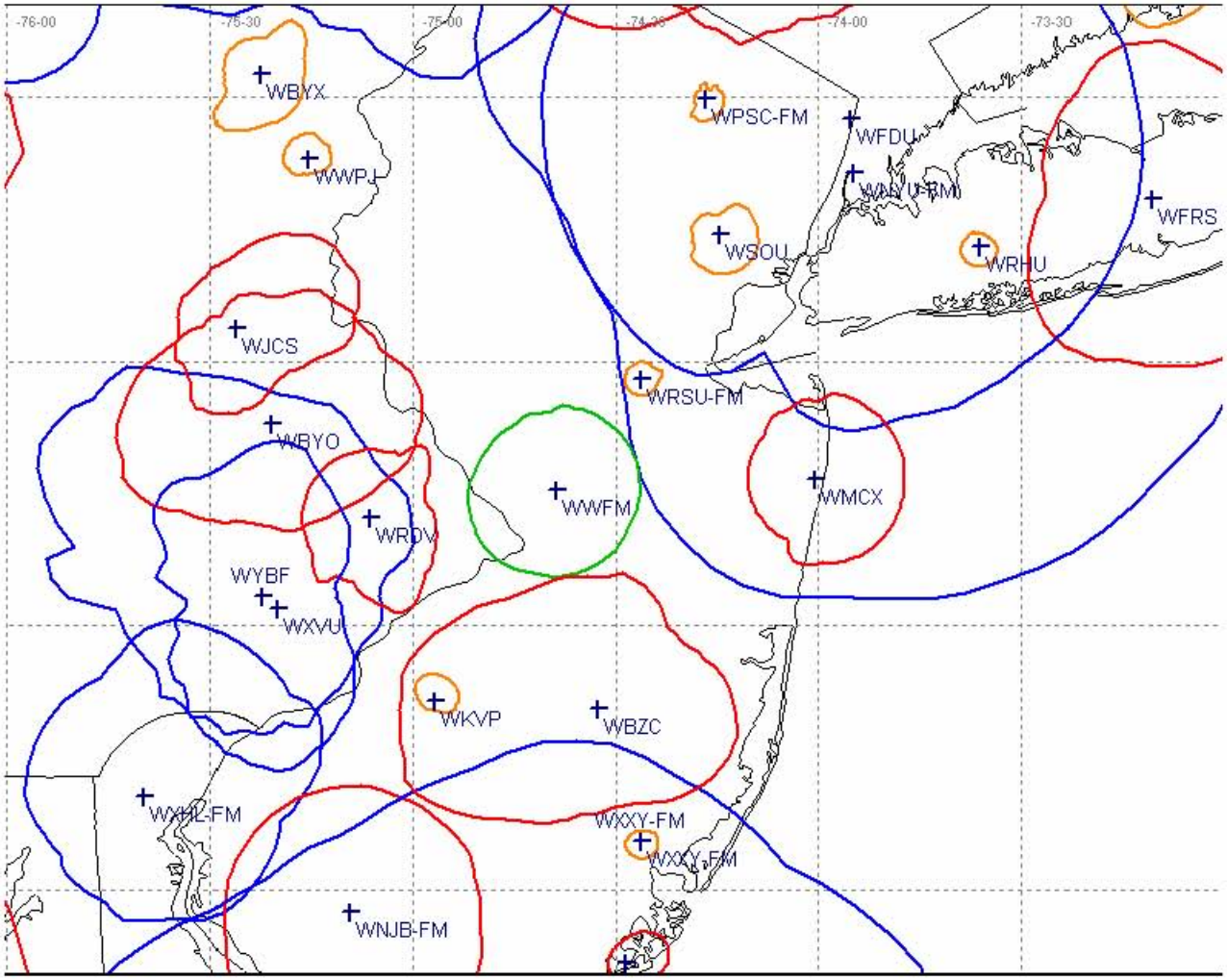
WNCU, Durham, North Carolina
Route Map with IBOC DAB Receive Status



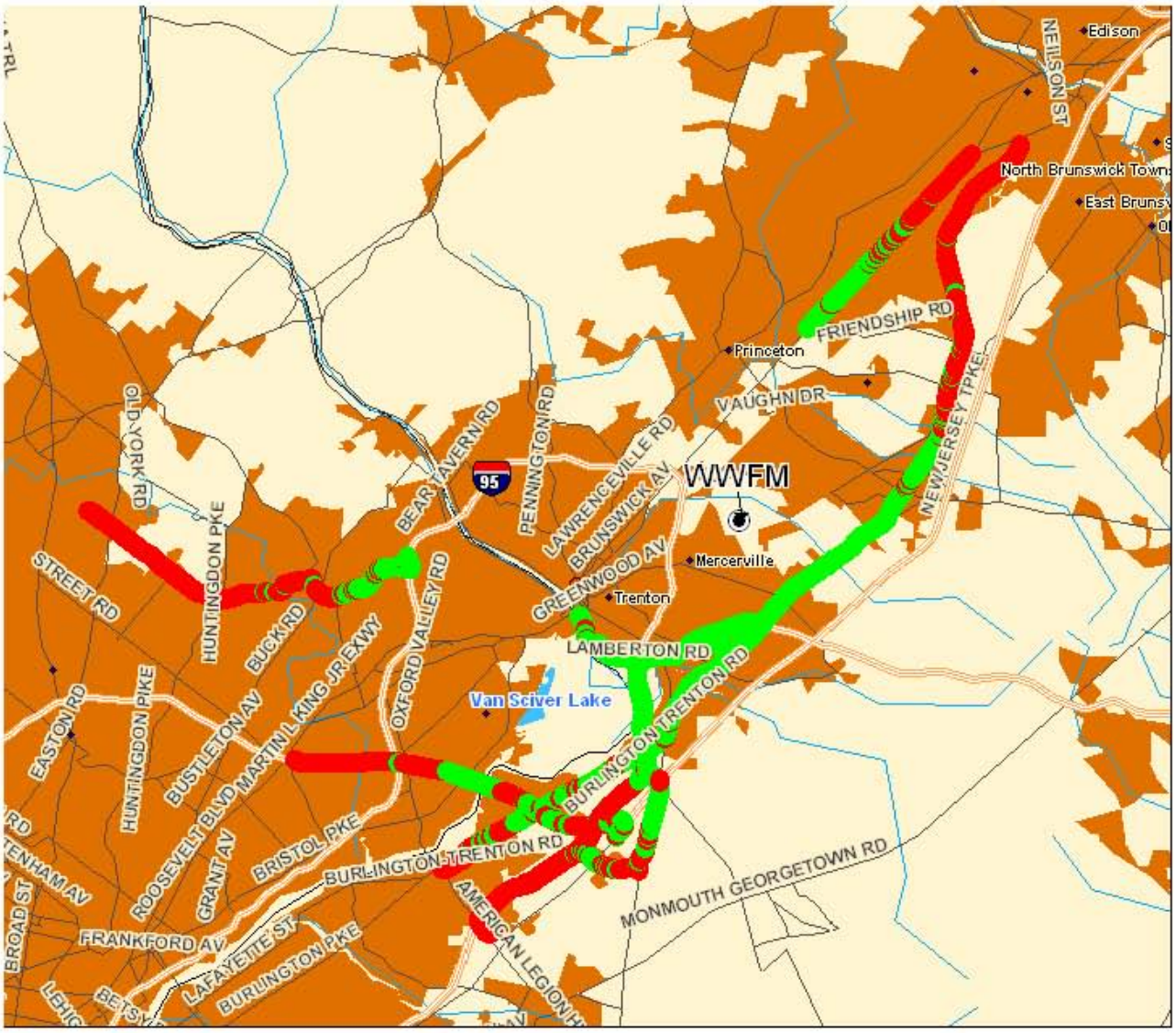
WNCU, Durham, North Carolina
Drive-test Signal Measurements



WWFM, Trenton, New Jersey
Ch. 206A, 1.15 kW, 89 m
F(50,50) 60 dBu Contour And Standard Interference Contours of Neighboring Stations



WWFM, Trenton, New Jersey
Route Map with IBOC DAB Receive Status



WWFM, Trenton, New Jersey
Drive-test Signal Measurements